UTILIZATION OF WASTE HEAT TO GENERATE USEFUL ELECTRIC CURRENT IN ELECTRIC VEHICLES

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Abstract
High requirement of energy has led to over exploitation of the non – renewable energy resources. Unfortunately the efficiency of this energy is also low. In automobiles, only 1/3 of energy is utilized and 2/3 of energy is released in the form of (waste) heat. A thermoelectric generator is a device that converts some of the waste heat generated by a heat source into electricity using a phenomenon called the seebeck effect. Electric vehicles in the market are facing the issue of less range than promised by the company due to various factors. If some the waste heat generated from the vehicle can be converted back into electricity, then possibly the range can be improved. In this project a drum brake of a two wheeler moped has been used to generate heat, the goal being to measure the output voltage and try to achieve the maximum possible output from the setup.

Keywords: waste heat recovery, seebeck effect, drum brake, thermo electric generator

Introduction

A thermoelectric generator (TEG), also called a Seebeck generator, is a solid state device that converts heat flux (temperature differences) directly into electrical energy through a phenomenon called the Seebeck effect [1]. Thermoelectric generators function like heat engines, but are less bulky and have no moving parts. However, thermo-electric generators are typically more expensive and less efficient. Thermoelectric generators could be used in power plants to convert waste heat into additional electrical power and in automobiles as automotive thermoelectric generators (ATGs) to increase fuel efficiency [2]. There has been a lot of research into the recovery of waste heat. One leading way is to use the technology of thermoelectric generators.

Thermoelectric generators are devices which convert heat energy into electrical energy and vice-versa. These are semiconductors works with the principle of thermoelectric effect. For waste heat utilization, these generators offer a high potential. It has been experimentally derived that the electrical power generation for thermo electric generator is a function of flow rate and inlet exhaust temperature from automotive TEGs. Also an experimental observation derived that voltage, current, power developed and efficiency of the system increases with increase in engine load[3]. The placement of TEG module in between catalytic converter and sub-muffler of the exhaust manifold is widely observed [4].

A similar automotive TEG model uses two different ‘add on’ parts which have different thermal properties are installed on the hot and cold junctions respectively and placed in a vacuum to enhance the current output of the TEG in an attempt to increase the efficiency of TEG module [5]. The manufacturing of thermoelectric modules is done by coupling two conjugate p-type and n-type doped semiconductor material in an optimized manner [6].

The ceramic plates are commonly made from alumina (Al2O3), but when large lateral heat transfer is required, materials with higher thermal conductivity are desired [7]. Recently developed ceramic material based generators are designed for a maximum operating temperature of 1000 °C, but in the

past, materials are made out of Bismuth Telluride and are restricted to the temperatures below 400°C.

Seebeck Effect

The Seebeck effect is a phenomenon in which a temperature difference between two dissimilar electrical conductors or semiconductors produces a voltage difference between the two substances. When heat is applied to one of the two conductors or semiconductors, heated electrons flow toward the cooler one.

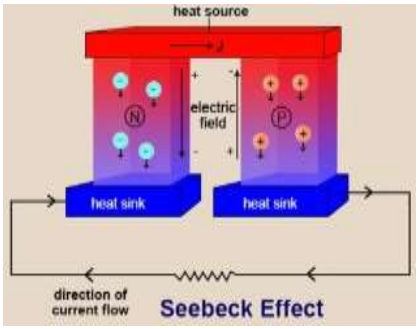

Fig 1: Seebeck Effect

Peltier Effect

The Peltier effect is the reverse phenomenon of the Seebeck effect; the electrical current flowing through the junction connecting two materials will emit or absorb heat per unit time at the junction to balance the difference in the chemical potential of the two materials.

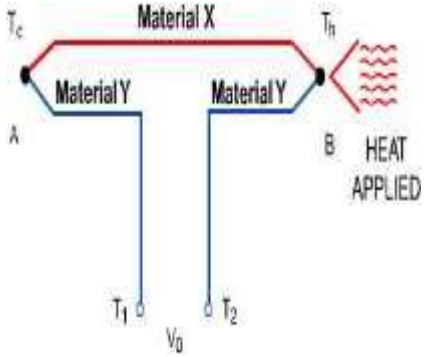

Fig 2: Peltier Effect

Joule heating phenomenon

Joule heating, also known as resistive, resistance or Ohmic heating, is the process by which the passage of an electric current through a conductor produces heat. Joule's law states that the power of heating generated by an electrical conductor equals the product of its resistance and the square of the current [9].

Statement of the problem

A fair amount of heat is generated by the brakes of a vehicle while it is running in the city due to heavy traffic which causes frequent braking, by converting this waste heat into current by using a thermo electric generator, the range of electric vehicles can be improved.

Objectives of the study

1. To measure the voltage generated
2. To maximize the output voltage
3. To connect to a suitable load

Review of literature

Sri Sabarinathan. R et.al (2018) experimentally derived that the electrically power generation for thermo electric generator is a function of flow rate and inlet exhaust temperature. The output voltage, according to Seebeck effect also increases as temperature difference increases.

Gregory P. Meisner (2011) developed a thermoelectric generator for automotive waste heat recovery. It includes the study of thermoelectric materials for development of thermo-electric generators. This model is capable of computing the overall heat transferred, the electrical power output, and the associated pressure drop for given inlet conditions of the exhaust gas and the available thermo-electric generator volume.

S.V Chavan et.al (2017)**,** experimentally observed that voltage, current, power developed and efficiency of the system increases with increase in engine load, exhaust temperature and flow rate of cooling water.

Components Used

DC Motor

Fig 3 is a stepper motor, also known as step motor or stepping motor is a brushless DC electric motor that divides a full rotation into a number of equal steps. The motor's position can be commanded to move and hold at one of these steps without any position sensor for feedback (an open-loop controller), as long as the motor is correctly sized to the application with respect to torque and speed.

Fig 3: DC motor

Drum brake

Drum brakes are widely used at the rear wheel, but also for both front and rear wheel in some cases. It uses brake shoes or brake pads to create a braking force. A drum brake assembly consists of brake shoes, springs, brake cable, brake drum, brake arm, brake cam, dust seal, anchor pin washer and brake panel.Each brake assembly consists of two shoes, primary and secondary. The primary shoe is located towards the front of the vehicle and has the lining positioned differently than secondary shoe.

Wheel

The wheel is a normal two wheeler type with a rim size of 10 inches. It has a sprocket welded to its side using three small brackets. It has an 8mm shaft at the centre which is welded to the frame to provide support to the rotation of the wheel. A slip ring it attached to the wheel to help measure the electric output from the thermo electric generator.

Frame

Mild steel square pipe of 19mm side and 16 gauge thickness is used to make the frame; the joints are welded together to dimensions to accommodate all the necessary components. Mild steel is used for this purpose as it is easily available and effectively priced.

Thermo electric generator

The thermo electric generator used for this experiment is of bismuth telluride make. The cover plate is made up of ceramic as it can withstand reasonably high temperature (~200 °C). The module dimensions are 40mm*40mm*40 mm (L*B*H) and it weight is approximately 25g. The maximum

working temperature of this thermoelectric generator is around 150°C. Fig 4 shows a thermoelectric generator.

Fig 4: thermoelectric generator

Multi-meter

A digital multimeter is a test tool used to measure two or more electrical values—principally voltage (volts), current (amps) and resistance (ohms).

Heat sink

Aluminum Square Fin heat sink. Aluminum is the most common material for heat sinks as it is lightweight and has relatively good thermal conductivity and high strength between 70 and 700 MPa. It is easy in machining.

Voltage Booster

Any acceptable DC source such as batteries, solar panels, rectifiers and DC generators can be used to power the boost converter. DC to DC conversion is the process of changing one DC voltage to another DC voltage. A boost converter is a DC to DC converter that produces a higher output voltage than the input voltage. Because it steps up the source voltage, a boost converter is also known as step-up converter. The booster converter comprises of a capacitor, resistor, and a transistor. Also the booster converter will boost up the voltage more than the given input voltage.

Experimental setup

The Drive consists of a 24V D.C motor which makes up to 250W power at is used to drive the wheel assembly. Wheel assembly: the wheel assembly is made of typical of 10 inches rim size wheel. The wheel is fixed onto a shaft and sprocket and fitted on the frame, the motor drives the wheel assembly by means of a chain. Brake setup: a typical drum brake of a two wheeler is used. It is fitted onto the wheel. A brake lever is fabricated to engage the brake. Electric power generation: the TEG is fixed to the Aluminum drum, the thermo-electric generator is connected to a digital voltmeter which measures the voltage generated and the voltmeter is connected to a suitable load. Fig 5 shows the picture of the experimental setup.

Fig 5: experimental setup

Working

Set of thermo-electric generators is fixed onto the brake drum. Aluminum heat sinks are mounted on the surface of thermo-electric generator to increase rate of heat removed through convection & maintain temperature of thermo-electric generator. The thermo-electric generator is connected to a voltmeter to measure the potential difference and in turn measure the current generated by thermo-electric generator. The generated current is connected to a suitable load to power it which in turn helps to reduce the load acting on the battery.

Results and Discussion

The experiment was conducted for two types of connections of the TEGs, series and parallel. Fig 6 shows the graphical plot of the readings recorded in parallel connection and fig 7 shows the graphical plot of the readings in case of series connection.

A. Parallel connection

TABLE 1: VOLTAGE READINGS IN PARALLEL CONNECTION

Sl. No.	Drum temp(°C)	Room temp(°C)	ΔT(°C)	Voltage(V)
1	30	27	3	0.090
2	35	27	8	0.114
3	40	27	13	0.123
4	45	27	18	0.135
5	50	27	23	0.156
6	55	27	28	0.175
7	60	27	33	0.213

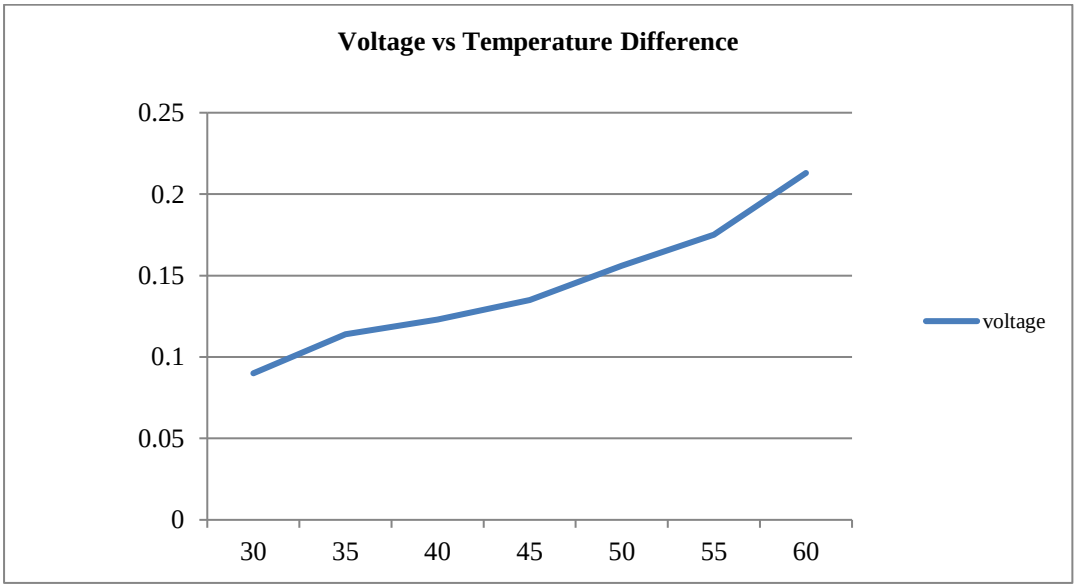

Fig 6: Voltage readings in Parallel Connection

B. Series connection

TABLE 2: VOLTAGE READINGS IN SERIES CONNECTION

Sl. No.	Drum temp(°C)	Room temp(°C)	ΔT(°C)	Voltage(V)
1	30	27	3	0.233
2	35	27	8	0.388
3	40	27	13	0.452
4	45	27	18	0.486

5	50	27	23	0.631
6	55	27	28	0.747
7	60	27	33	0.897

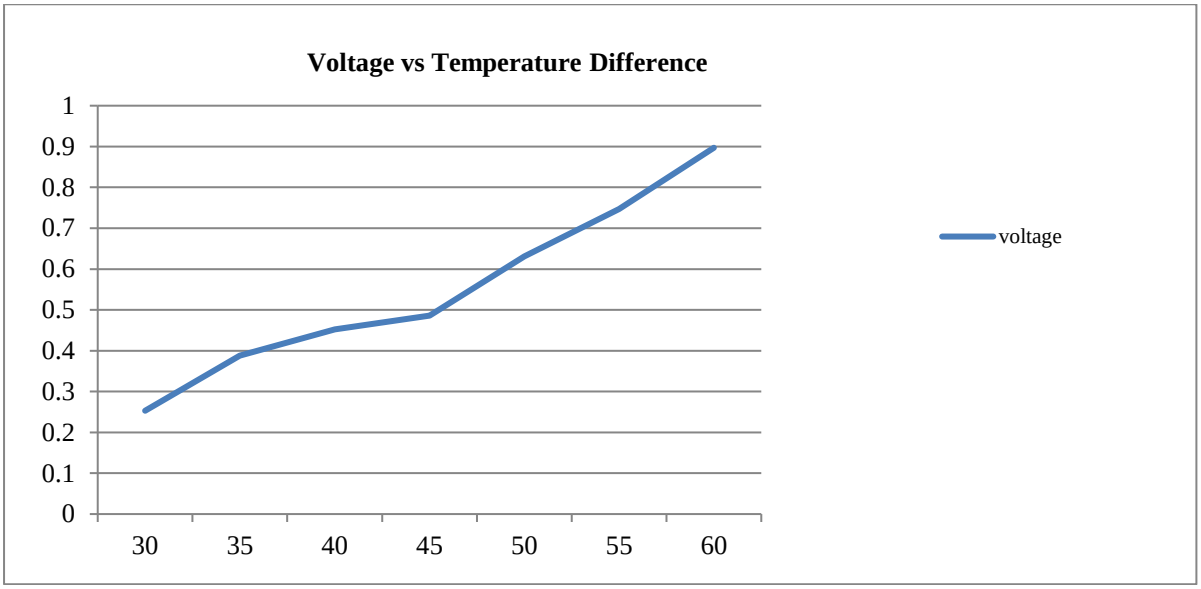

Fig 7: Voltage readings in Series Connection

When connected in parallel, each of the thermoelectric generator can generate a voltage around 0.2V at 60°C, and when connected in series the voltages get added up to generate around 1V at 60°C. It can be observed that Thermo Electric Generator is more efficient when connected in series manner. A graph has been plotted showing the voltage generated at different temperatures of the brake drum, we can observe the trend at which the thermoelectric generators are generating the voltage. From the second graph, we can observe that the Thermo Electric Generators can produce close to 1 V at 60° C temperature, by following this trend we can imply that at 70 to 80° C. The thermoelectric generators will produce over 1.5 to 2 V.

The obtained output voltage can be increased by the use of booster circuit which will enhance the applications for the generated potential difference.

C. Boosted voltage

TABLE 3: BOOSTED VOLTAGE READINGS

Sl. No.	**Output voltage (V)**	**Boosted voltage (V)**
1	0.631	5
2	0.747	5
3	0.897	5

A voltage booster is a device that is used to increase the voltage output of a system. The output from the series thermoelectric generators has been connected to the voltage booster and the respective values were measured. The booster has a minimum trigger value of 0.5V and is able to boost any voltage above 0.5V to 5V. The final output from this circuit is at 5v which is sufficient to power a wide range of electronics onboard the vehicle such as phone charger, sensors and LED indicators.

Conclusion

By using a thermoelectric generator for this application of waste heat recovery, we can generate a reasonable voltage which can be used to power a small component in an electric vehicle such as a USB charging port or any sort of LED indicator by connecting to a booster circuit. This method could be an option for cost cutting by offering a regeneration opportunity at a lower cost. Frequent

braking of a vehicle in traffic conditions causes the brake to heat well over 70°C, hence generating around 1.5V. By the output obtained from the experimental setup it can be concluded that this gained output voltage from the heating of brake drum can be utilized for many sorts of external load in the electric vehicle applications.

Acknowledgement
The authors acknowledge all the papers for the useful information; they acknowledge the support extended by the college for providing the lab facilities and the faculty for their guidance.

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