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Power Generation from Waste Heat by Thermo- Electric Generator

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Abstract

The increasingly worldwide problem regarding rapid economy development and a relative shortage of energy, the internal combustion engine exhaust waste heat and environmental pollution has been more emphasized heavily recently. Out of the total heat supplied to the engine in the form of fuel, approximately, 30 to 40% is converted into useful mechanical work. The remaining heat is expelled to the environment through exhaust gases and engine cooling systems, resulting in to entropy rise and serious environmental pollution, so it is required to utilized waste heat into useful work. As waste heat recovering techniques, such as thermoelectric generator (TEG) is developed. Due to distinct benefits of Thermo-electric generators they have become a promising alternative green technology.

Keywords: *Power generation, Seebeck effect, Thermo-electric generator, Waste-heat, recovery, Alternative green technology, Direct energy conversion, Thermal heat*

INTRODUCTION

Recently we are depending upon fossil fuels for maximum electricity generation. However, the reserves of fossil fuels will be goes on depleting, since oil & gas are the least sources. Recent years cost of unit electricity has increasing to unpredictable levels due the less supply of (oil gas coal). Thus the green energies are more attractive artificial to electricity generation, as it will also provide pollution free and cost less.

In this project we are generating electrical power as non-conventional method by heat energy Non-conventional energy systems very essential at this time to our nation. In this project a mechanical arrangement is made. Use of embedded technology makes this system efficient and reliable. This invention relates to the Internal Combustion Engine. Among all research directions, waste heat recovery (WHR) is most concerned, due to the widespread existence and high accessibility of suitable resources. While there are a number of devices to fulfill WHR, thermoelectric generator (TEG) has been utilized in most automotive applications. A thermoelectric power generator is a solid s device waste heat energy into electrical energy. Conversion of thermal energy (heat) into electricity is based on "Seeback effect" directly. Here there is charge movement in the media. Advantages of Thermoelectric power generators are extremely reliable (typically exceed 100,000 hours of steady-state operation) and silent in operation; Since they have no mechanical moving parts and require considerably less maintenance; They are simple, compact and safe; They have very small size and virtually weightless; They are capable of operating at elevated temperatures; They are suited for small-scale and remote applications Typical of rural power supply, where there is limited or no electricity; They are environmentally friendly; They are not position-dependent and they are flexible power sources.

OBJECTIVES

The current research is focusing on a technology, which is able to convert the thermal energy contained in the exhaust gas directly into electric power. In this project concept it invented exhaust gas-based thermoelectric power generator for an industry application. In this the exhaust gas gases in the pipe provide the heat source to the thermoelectric power generator. The key is to directly convert the heat energy from automotive waste heat to electrical energy using a thermoelectric generator. While the electric power generation by such a system is able to generate is still relatively small at a maximum of 10 W from a single TEG module, rapid progress in materials research can make the ambitious objective of generating higher watts by all means of feasible proposition.

Data Collection

Internal combustion engine approximately 30 to 40% is converted into useful mechanical work. The remaining heat is expelled to the environment through exhaust gases and engine cooling systems.

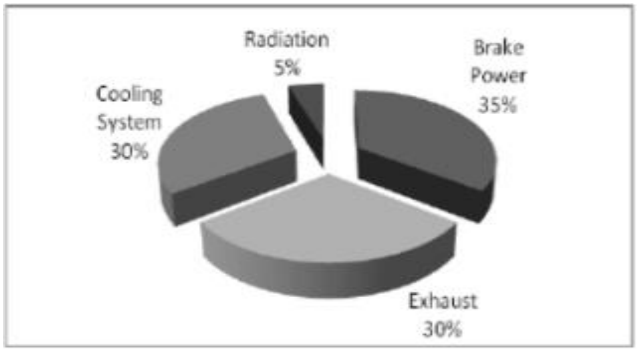


Fig.1-Fuel Energy Content in IC Engine

It means approximately 60 to 70% energy losses as a waste heat through exhaust (30% as engine cooling system and 30 to 40% as environment through exhaust gas). Exhaust gases immediately leaving the engine can have temperatures as high as 842-1112°F [450-600°C]. Consequently, these gases have high heat content, carrying away as exhaust emission.

LITERATURE SURVEY

Method for generating power such as burning of wood, petrol, diesel, coal, is continuously depleting with nature, so that exceeded usage of electricity according to the consumer demand. Global warming is the increase in the average measured temperature of the Earth's near surface air and Oceans since the mid-20th century, and its projected continuation. Global surface temperature increased 0.74 ± 0.18 °C (1.33 ± 0.32 °F) during the Thomas Jon Seebeck (1934) invented that a temperature formed between two dissimilar conductors produces a voltage and current. At the heart of the thermoelectric generator effect is the fact that a temperature difference in a conducting material results in heat flow between one side to another side. There are different type of research on power generation from heat is present.

Jihad G. Haidar, Jamil I. Ghojel, "waste heat recovery from the exhaust of low-power Diesel engine using thermoelectric generators, 20TH international conference on thermoelectric (2001), p413-417, this shows how to recover waste heat and how to utilize waste heat from different industries.

Mariem SAIDA, Ghada ZAIBI, Mounir SAMET, Abdennaceur KACHOURI, A new design of thermoelectric generator for health monitoring, 2017 International Conference on Smart, Monitored and Controlled Cities (SM2C), Kerkennah,

Tunisia, February, 17-19, 2017, p 59-63 , from this we analyses about thermoelectric generator and its specification.

Ahaad Hussein Alladeen, Shanshui Yang, Yazhu Liu, Feng Cao, Thermoelectric waste heat recovery with cooling system for low gradient temperature using power conditioning to supply 28V to a DC bus, 2017 IEEE Transportation Electrification Conference and Expo, Asia-Pacific (ITEC Asia- Pacific), 2017 , we studied different types of cooling system and different types of coolant. Arash Edvin Risseh, Electrical Power Conditioning System for Thermoelectric Waste Heat Recovery in Commercial Vehicles, IEEE Transactions on transportation electrification, 2018, p 2-16, got an idea about how to recover the waste heat from automobile application.

This section gives the brief description of each component used in designing the waste heat to generate electricity By using this thermoelectric power generation (TEG) devices shown Whenever heating of one surface (waste heat example refrigerator outer surface heat, laptop heat, ion box heat, solar radiation heat, even human body heat) is also an input of thermo electric generator.

When heat is applied one side there will be a continuous electron or holes will flow continuously based on the temperature of heat. If the temperature is increases the voltage is also increases vice versa in such a way that the other side of thermoelectric generator is cold because heat transform is uniform then only electron will flow and voltage is developed at the output side of the thermoelectric generator.

Block diagram

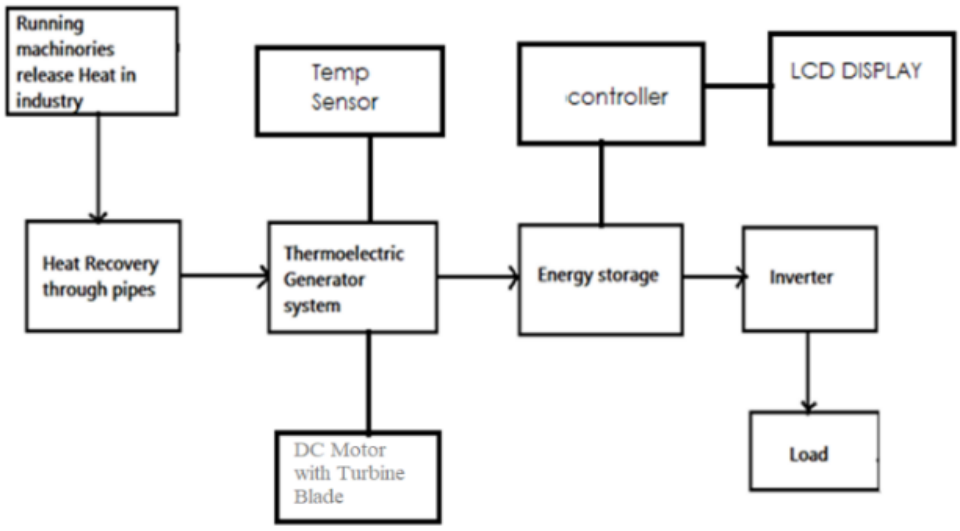
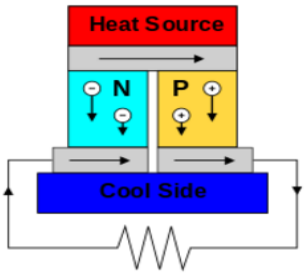


Fig.2- Block Diagram

Thermo-electric Generator

A thermoelectric generator (TEG) is an electric device that converts heat energy produced from a heat source directly into electrical energy. This phenomenon is called the Seebeck Effect, named after Thomas Johan Seebeck. Thermoelectric generators (TEG) are solid-state semiconductor devices that convert a temperature difference and heat flow into a useful DC power source. This generated voltage drives electrical current and produces useful power at a load.

Thermoelectric generator works in a very simple manner as it converts heat energy to electricity. It can be used to make an electric current flow through a metallic surface and thus protect it from corroding.



Here the cool side represents a metallic surface that needs to be protected from corrosion. TEG's are capable of converting heat energy to electric current that can flow across the metal. A TEG has a sealed thermoelectric module called a thermopile and contains an array of semiconductors. The temperature difference across the thermopile creates a DC current, which flows across the cooler side (i.e., the metallic surface).

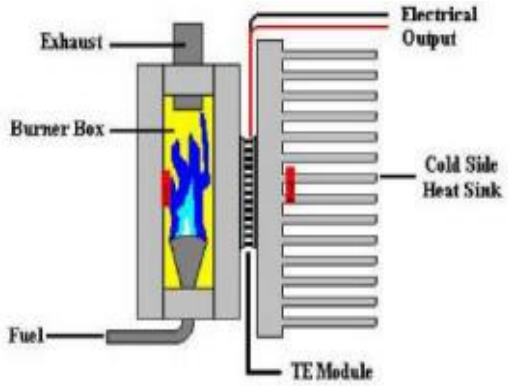


Fig.3 -Thermoelectric Generator

Temperature Sensor

A temperature sensor is a device that is designed to measure the degree of hotness or coolness in an object. The working of a temperature meter depends upon the voltage across the diode. The temperature change is directly proportional to the diode's resistance. The cooler the temperature, lesser will be the resistance, and vice-versa. The basic principle of working of the temperature sensors is the voltage across the diode terminals. If the voltage increases, the temperature also rises, followed by a voltage drop between the transistor terminals of base and emitter in a diode.

The resistance across the diode is measured and converted into readable units of temperature (Fahrenheit, Celsius,

Centigrade, etc.) and, displayed in numeric form over readout units. In geotechnical monitoring field, these temperature sensors are used to measure the internal temperature of structures like bridges, dams, buildings, power plants, etc.

Heat recovery pipes

Having first been invented near the turn of the 20th century, the heat pipe is not in itself a new invention. Early heat pipes were constructed out of hollow metal tubes that were sealed at both ends, vacuumed, and charged with a small quantity of evaporative fluid. They contained a "wick" to transport the fluid from one end of the heat pipe to the other.

Relying on the energy absorbed and released from the phase change of the fluid, the hollow heat pipe allowed an extremely fast heat transfer. Heat applied to one end of the pipe would almost instantaneously evaporate the fluid inside. This vapor would then move to the other, colder end of the pipe where it quickly condensed back into a liquid, releasing the heat absorbed during the evaporation.

DC Motor

A direct current (DC) motor is a type of electric machine that converts electrical energy into mechanical energy. DC motors take electrical power through direct current, and convert this energy into mechanical rotation. DC motors use magnetic fields that occur from the electrical currents generated, which powers the movement of a rotor fixed within the output shaft. The output torque and speed depends upon both the electrical input and the design of the motor.

DC fans the direct current fans, or DC fans, are powered with a potential of fixed value such as the voltage of a battery. In contrast, the alternating current fans, or AC fans, are powered with a changing voltage of positive and of equal negative value.

Inverter

An inverter is an electrical apparatus that changes direct current to alternating current. It is not the same thing as an alternator, which converts mechanical energy into alternating current. Direct current is created by devices such as batteries and solar panels. When connected, an inverter allows these devices to provide electrical power for small household devices. The inverter does this through a complex process of electrical adjustment. From this process, AC electric power is produced. This form of electricity can be used to power an electric light, a

microwave oven, or some other electric machine.

An inverter usually also increases the voltage. In order to increase the voltage, the current must be decreased. So, an inverter will use a lot of current on the DC side when only a small amount is being used on the AC side.

LCD display

LCD (Liquid Crystal Display) is a type of flat panel display which uses liquid crystals in its primary form of operation. LEDs have a large and varying set of use cases for consumers and businesses, as they can be commonly found in smartphones, televisions, computer monitors and instrument panels.

LCDs were a big leap in terms of the technology they replaced, which include light-emitting diode (LED) and gas-plasma displays. LCDs allowed displays to be much thinner than cathode ray tube (CRT) technology. LCDs consume much less power than LED and gas-display displays because they work on the principle of blocking light rather than emitting it. Where an LED emits light, the liquid crystals in an LCD produce an image using a backlight.A display is made up of millions of pixels. The quality of a display commonly refers to the number of pixels; for example, a 4Kdisplay is made up of 3840 x2160 or 4096x2160 pixels.

PROJECT PRINCIPLE

Seebeck Effect

The Seebck 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 conductor or semiconductor. If the pair is connected through an electrical circuit, direct current (DC) flows through that circuit. The Seebeck effect is a major observation in the study of physics.

It is widely used in the application of semiconductors and conductors, and thus, has a lot of practical applications for us in our daily lives. German physicist Thomas Jonahan Seebeck was the one who formulated this, when he noticed that a magnetic compass, when brought in close proximity of two semiconductors can undergo a variation.

What is the Seebeck Effect?

In 1821, German physicist Thomas Seebeck had observed the properties of the

thermoelectric effect. It was seen that a circuit that had two different metals developed an EMF when their junctures were maintained at different temperature levels. These non-similar metals form what is known as a thermocouple, and the current that passes through this circuit is known as thermoelectric current.

The Seebeck effect explained the production of an electromotive force and the electric current in a loop of materials consisting of at least two dissimilar conductors maintained at two different temperatures, known as the thermocouples. It can be termed as the Seebeck effect thermocouple. The Seebeck effect is a reversible process. If the hot and cold junctions are interchanged then the direction of the current will also change. Therefore, the thermoelectric effect is a reversible process. The magnitude and sign of thermo EMF depend on the materials of the two conductors and the temperature of the hot and cold junction.

Seebeck after discovering thermal properties of different pairs of metals arranged in series is called thermoelectric series. The thermoelectric effect is the conversion of temperature differences into electrical potential differences or vice versa using a thermocouple.

The Seebeck effect is the best example of an electromotive force. Through the Seebeck effect, we can also calculate the measurable electric currents or voltages in the same way as electromotive forces.

The Seebeck coefficient implies that a certain potential is induced in the circuit per change in temperature. It should be remembered that the Seebeck coefficients can change with temperature and they are dependent on the composition of the conductor. Usually it has been noticed that at room temperature, the Seebeck coefficient ranges between -100V/K to 1000V/K.

PROJECT WORKING

Non-conventional energy using is converting mechanical energy into the electrical energy. Here in this project a power generation arrangement is made. Use of thermoelectric principle makes this system efficient and reliable. In vehicles engine continuously run for their operation. It release large amount of heat. This is wastage heat. We utilized this wastage heat to produce electricity When we apply TEG with Heat sink module to wastage heat through heat pipe executed from silencer. Then at the same time TEG starts converting Heat energy into Electrical energy.

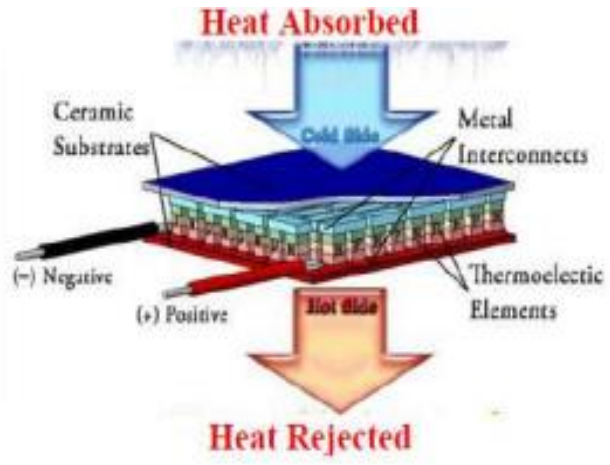


Fig.4 - Operating principle of thermo-electric module

We can measure this heat with the help of temperature sensor attached to the system. One DC fan is attached to system to indicate the flow and conversion of heat energy into Electrical energy. As the amount of temperature is increases, the flow of fan is also increases. Generated electrical energy is stored in battery. This stored energy is supply to inverter to convert DC to AC. At the output AC load is obtain. This AC load is utilized to run various loads in same industry like, fan, AC, light etc.

Start from wastage of heat dissipated through silencer in vehicles. Then conversion of heat into electricity and the indication of conversion electricity through DC fan and motor. Storage of electricity in battery. Conversion of DC voltage to AC voltage with help of inverter. If such system utilized in all type of automobiles, the amount of wastage heat can be reduced and we can utilized into electricity.

DESIGN CALCULATIONS

Calculation for Voltage generated:-

From the equation of Seebeck effect,

$V=\alpha (Th - Tc)$

Where, **V** – Voltage Generated in Volts

α – Seebeck coefficient in **μV/K**

Th - temperature of hot surface (silencer) in Kelvin

Tc-temperature of cold surface (atmosphere) in Kelvin, Tc = 303 k.

RESULT

Benefits of ‘waste heat recovery’ can be broadly classified in two categories

Direct Benefits

Recovery of waste heat has a direct effect on the combustion process efficiency. This

is reflected by reduction in the utility consumption and process cost.

Indirect Benefits:

a) Reduction in pollution: A number of toxic combustible wastes such as carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx), and particulate matter (PM) etc, releasing to atmosphere. Recovering of heat reduces the environmental pollution levels.

b) Reduction in equipment sizes: Waste heat recovery reduces the fuel consumption, which leads to reduction in the flue gas produced. This results in reduction in equipment sizes.

c) Reduction in auxiliary energy consumption: Reduction in equipment sizes gives additional benefits in the form of reduction in auxiliary energy consumption.

The experimental results obtained are tabulated as follows:

Table 1: Voltage generated and boosted for different temperatures

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

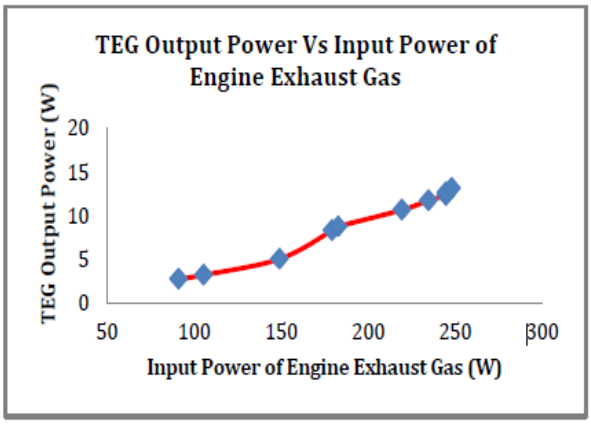


Figure: TEG Output Power Vs Input Power of Exhaust heat Gas

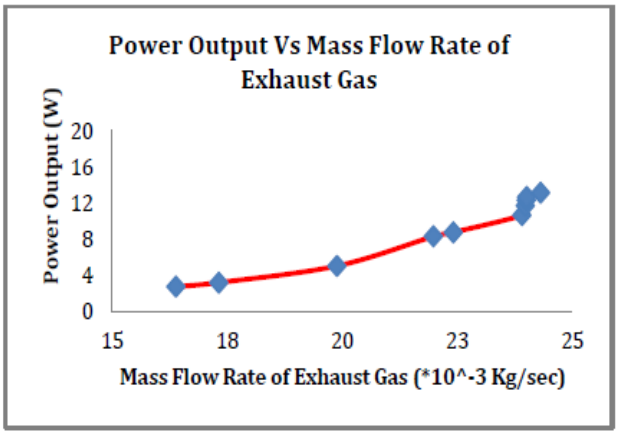


Figure: Power Output Vs Mass Flow Rate of Exhaust Heat Gas

The graph shows that the power output is function of mass flow rate of exhaust gas. At the mass flow rate of exhaust gas of 24.317 Kg/sec the power developed by TEG system is average 10 W.

Waste heat recovery entails capturing and reusing the waste heat from internal combustion engine and using it for heating or generating mechanical or electrical work. It would also help to recognize the improvement in performance and emissions of the engine if these technologies were adopted by the automotive manufacturers.

THE SCOPES

1. By using thermoelectric generator connecting in series /parallel we can generate the power for maximum level.
2. Even body heat also generates the heat that can be utilizing by using TEG to generate the power to charge the portable equipment like laptop mobile etc.
3. By installed in the vehicle above the radiator means the vehicle battery will charge self.

ADVANTAGES

- Clean, Noise less, Cost is less.
- This is a Non-conventional system, No fuel is require.
- Easy maintenance, portable, charging time is less (maximum temp).
- Promising technology for solving power crisis to an affordable extent.
- Simple in construction, Pollution free, Reduces transmission losses.
- Wide areas of application Required less space.

- It can use at any time when it necessary.
- Less number of parts required.
- Electricity can use for many purposes.
- Efficient and eliminate the grid searching.

DISADVANTAGES

Improper variation of temperature gradient difference may damage the TEG, Complex design

APPLICATIONS

- Thermoelectric Generators are basically used in where the power production is less.
- In many industries amount of heat is executed and been wastage
- In automobile vehicle produce heat that can be used for generating electricity by using TEG.
- Recharge the battery where ever waste heat is obtained.
- Self-charging battery by fixing the TEG at radiator or two wheeler silencers pipe.

CONCLUSION

Waste heat recovery entails capturing and reusing the waste heat from machineries in industries and using it for generating electrical work. It would also help to recognize the improvement in performance and emissions of the machineries if these technologies were adopted by the production industries.

If this concept of thermoelectric system is taken to the practical level then there will be large amount of electricity can be generated, which will be used to run industrial load itself. Also large amount of wastage heat for pollution is also uses in this system in continue manner. And such industries also somehow help to protect the environmental pollution.

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