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RECOVERING EXHAUST HEAT TO GENERATE ELECTRICITY AND BOOST EFFICIENCY

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ABSTRACT

Now a day an automobile has become one of the basic needs of the human being. In spite of several advantages, an automobile also possesses some of the few drawbacks. These drawbacks may be high prices of the fuel, low vehicle efficiency, pollution etc.. So it had become necessary to the scientists and researchers to find the remedies to overcome the drawbacks caused due to an automobile. Since all of us knows that there is a tremendous amount of energy dissipating from the exhaust of the vehicle. This form is already termed as the waste energy. But scientists and researchers have already found way to recover this waste energy into other form of energy. Waste energy is in the form of heat energy i.e. thermal energy. Thermal energy an be converted into electrical energy. For this purpose we have to implement thermoelectric generators (TEG). These generators are somewhat different from the ordinary generators. Thermoelectric generators do not posses any moving components like rotors, fans, pumps, motors etc.. These thermoelectric generators work on the principle of 'Seebeck effect'. Thermoelectric generators, or TEGs, are devices that utilize one or more thermoelectric modules as the primary component/s, followed by a cooling system that can be either passive or active: such as an open air heat sink, fan cooled heat sink, or fluid cooled. These components are then fabricated into an assembly to function as one unit called a thermoelectric generator. These thermoelectric generators are also used in automobile field to recover the exhaust heat into useful means of energy i.e. electrical energy. Thermoelectric generators are implemented on the exhaust part. Also the exhaust heat can be utilized to increase the temperature of inner vehicle in cold days. Also the thermoelectric generators are used to run the air condition of car. Also the exhaust gases could filtered at some amount and can be used for cleaning purpose when applied at high pressure. Thermoelectric generators have the efficiency of 5 to 8% only. Since developments have been going on to increase the efficiency. An automotive company BMW had already updated the thermoelectric generators. Thermoelectric materials are often used in thermoelectric generators. According to their thermal conductivity at different temperatures materials have used. Materials like bismuth telluride, lead telluride, inorganic calthrates, magnesium group compounds, sillicides, Skutteruditethermoelectric.etc are used.

I. INTRODUCTION

Automobile had evaluated a lot during this past period. Automotive had changed the human life. It has made the human life very comfortable. Precious time of human being has saved. Today it has become a basic necessity of human life. In spite of lot of advantages there are several disadvantages caused due to automobile. Recent whole world is facing the problems related to an automobile. These problems might be high prices of the fuel, pollution, low vehicle efficiency etc. These problems are harassing human being since an automobile has become one of the basic components of human life. Thus it was an obligatory for scientists and researchers to find remedies and various ways to overcome these problems .In automobile cars, vehicles large amount of energy is dissipated from exhaust part. As this energy is termed as waste energy, but suppose if this waste energy is utilized for generating electricity or any other form of energy. If this becomes possible it could earn some extent amount of efficiency. Large amount of heat energy i.e. thermal energy is dissipated from tail pipe. Thermal energy can be converted into electrical energy putting thermo electrical generators in operation. Thermoelectric generators are the devices that convert heat energy directly into electrical energy. The Thermoelectric generators (TEG) works on the phenomenon of the 'Seebeck effect'. Their typical efficiency is only 5 to 8%. These are solid state device having no moving parts like rotors, pumps, motors etc .Radioisotope thermoelectric generators can provide electric power for spacecraft. Automotive thermoelectric generators are proposed to recover usable energy from automobile waste heat. Since to increase the mileage of vehicle, the thermoelectric generators are installed on the vehicles. Substantial thermal energy is available from the exhaust gas in modern automotive engines. Two thirds of the energy from combustion in a vehicle is lost as waste heat, economy FE) by as much as 5%. A comprehensive theoretical study concluded that a TEG powered by exhaust heat could meet the electrical requirements of which 40% is in the form of hot exhaust gas. Use of TEGs has the potential to recover some of this waste energy in the exha ust stream, potentially improving fuel of a medium sized vehicle. These thermoelectric generators often use thermoelectric materials. . In this report further, we are going see thermoelectric generators. Also we will see the different thermoelectric materials.

1.1 Recovering Exhaust Heat to Boost Efficiency

According to the law of conservation of energy 'energy can neither be created nor be destroyed, but can be converted from one form to the other form.' All of us know that there is a tremendous amount of energy at the exhaust part of the vehicle. This is considered to be the waste energy. This is in the form of thermal energy. According to the researchers and scientists, by utilizing these thermal energy from exhaust could increase mileage of vehicle by 4 to 5%. If this became possible, this would establish a milestone in an automobile field. Human being feels comfortable at temperature from 25 to 30°c. If this temperature increases or decreases it could be too clumsy and uncomfortable to human being. In cold days temperature of the atmosphere is low. At this, waste heat from exhaust heat could be utilized to increase temperature of inner part of the vehicle. Also these waste gases if filtered at certain amount can be used for cleaning purpose in vehicle when ejected at high pressure while vehicle is running. This could minimize the cleaning and maintenance cost of the vehicle. Also the recovery of these waste gases could lower down the harmful emissions by providing the treatment to the waste gases. The tremendous heat from exhaust part could also be utilized to increase the temperature of the air fuel homogeneous mixture at the intake port of the combustion chamber. Also the exhaust can be used to generate electricity. Exhaust of the vehicle possesses lots of the harmful gases and mixture but proper application of these gases could increase the efficiency of the vehicle. Thus how the thermal energy from exhaust part of the vehicle can be used boost up the efficiency of the vehicle.

1.2 Recovering Exhaust Heat to Generate Electricity

Thermal energy can be converted into electrical energy by means of applying thermoelectric generator. Thermal energy from exhaust part could be utilized for the generation of electrical energy. Vehicle contains various systems like brake system, cooling system, electrical system etc.. Electrical system is one of the important system of the vehicle. Power factor of this system is battery. Continuous use of the battery decreases the concentration of the battery. This battery could get charged from exhaust system. As the exhaust system posses large amount of thermal energy, this energy could be converted into electric energy and thus battery will get charged. Also the electric energy produced could be used to run the other electrical appliances. This is all possible because of the thermoelectric generators.

1.3 Thermoelectric Generators

Thermoelectric generators are devices that convert heat (temperature differences) directly into electrical energy, using a phenomenon called the "Seebeck effect (or "thermoelectric effect"). Their typical efficiencies are around 5–8%. Older Seebeck-based devices used bimetallic junctions and were bulky. More recent devices use semiconductor p–n junctions made from bismuth telluride(Bi_2Te_3), lead telluride(PbTe), calcium manganese oxide, or combinations thereof, depending on temperature. These are solid-state devices and unlike dynamos have nonmoving, with the occasional exception of a fan or pump. Radioisotope thermoelectric generators can provide electric power for spacecraft. Automotive thermoelectric generators are proposed to recover usable energy from automobile waste heat.

1.4 Seebeck Effect

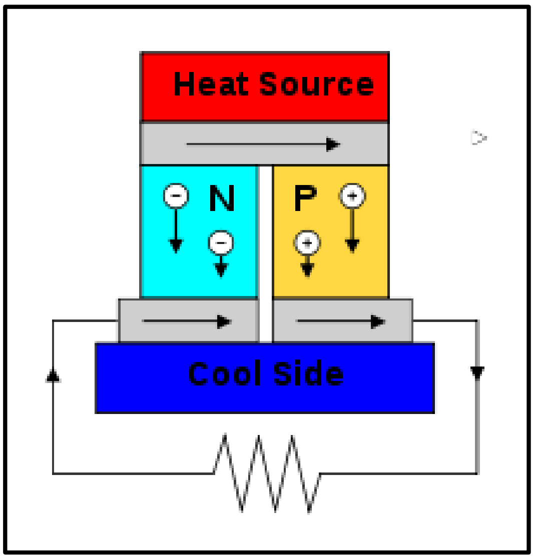

Fig 1: Seebeck effect.

A thermoelectric circuit composed of materials of different Seebeck coefficient (p-doped and n-doped semiconductors), configured as a thermoelectric generator. If the load is removed then the current stops, and the circuit functions as a temperature-sensing thermocouple.

The Seebeck effect is the conversion of temperature differences directly into electricity and is named after the Baltic German physicist Thomas Johann Seebeck, who, in 1821, discovered that a compass needle would be deflected by a closed loop formed by two different metals joined in two places, with a temperature difference between the junctions. This was because the metals responded differently to the temperature difference, creating a current loop and a magnetic field. Seebeck did not recognize there was an electric current involved, so he called the phenomenon the thermo magnetic effect. Danish physicist Hans Christian Ørsted rectified the mistake and coined the term "thermoelectricity".

II. LITURATURE REVIEW

The basic theory and operation of thermoelectric based systems have been developed for many years. Thermoelectric power generation is based on a phenomenon called “Seebeck effect” discovered by Thomas Seebeck in 1821 When a temperature difference is established between the hot and cold junctions of two dissimilar materials (metals or semiconductors) a voltage is generated, i.e., Seebeck voltage. In fact, this phenomenon is applied to thermocouples that are extensively used for temperature measurements. Based on this Seebeck effect, thermoelectric devices can act as electrical power generators. A schematic diagram of a simple thermoelectric power generatoroperating based on Seebeck effect is shown in Fig. (**1**). As shown in Fig. (**1**), heat is transferred at a rate of *H Q* from a high-temperature heat source maintained at *TH* to the hot junction, and it is rejected at a rate of *L Q* to a low- temperature sink maintained at *TL* from the cold junction. Based on Seebeck effect, the heat supplied at the hot junction causes an electric current to flow in the circuit and electrical power is produced. Using the first-law of thermodynamics (energy conservation principle) the difference between *H Q* and *L Q* is the electrical power output *e W*. It should be noted that this power cycle intimately resembles the power cycle of a heat engine (Carnot engine), thus in this respect a thermoelectric power generator can be considered as a unique heat engine.

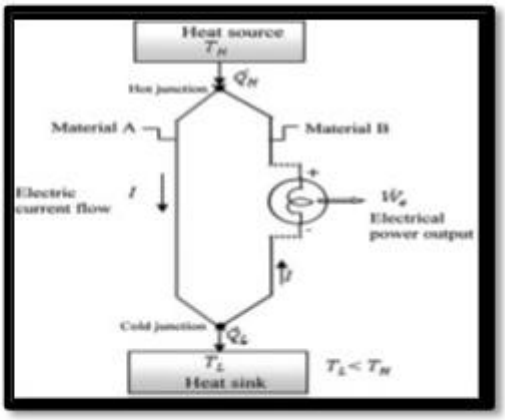

Fig 2: Schematic diagram showing the basic concept of a simple thermoelectric power generator operating based on Seebeck effect.

2.1 Uses

Thermoelectric generators can be applied in a variety of applications. Usually, thermoelectric generators are used for small applications where heat engines (which are bulkier but more efficient) would not be possible. Another deciding factor is that while inefficient, thermoelectric generators are more reliable and have a smaller chance of breaking over time and use. Spacecraft are a typical example of an application where maintenance is next to impossible after launch.

2.2 Application

- The most common application is the use of thermoelectric generators on gas pipelines.
- Many space probes, including the Mars Curiosity rover, generate electricity using a thermoelectric generator whose heat source is a radioactive element.
- Harvesting that heat energy, using a thermoelectric generator, can increase the fuel efficiency of the car.
- In wood stoves, outdoor boilers, cooking, oil and gas fields, pipelines, and remote communication towers thermoelectric generators are used.
- Microprocessors generate waste heat. Researchers have considered whether some of that energy could be recycled.
- Solar cells use only the high frequency part of the radiation, while the low frequency heat energy is wasted. Several patents about the use of thermoelectric devices in tandem with solar cells have been filed. The idea is to increase the efficiency of the combined solar/thermoelectric system to convert the solar radiation into useful electricity.

2.3 Efficiency

Thermoelectric generators typically have lower efficiency than mechanical generators such as Stirling engines, i.e. they generate less electric power for the same heat flow. Currently, TEGs are about 5% efficient. However, advancements in thin-film and quantum well technologies could increase efficiency up to 15% in the future. The efficiency of an ATEG is governed by the thermoelectric conversion efficiency of the materials and the thermal efficiency of the two heat exchangers. The ATEG efficiency can be expressed as:

$$\zeta_{OV} = \zeta_{CONV} \times \zeta_{HX} \times \rho$$

Where:

- ζ_{OV} : The overall efficiency of the ATEG
- ζ_{CONV} : Conversion efficiency of thermoelectric materials
- ζ_{HX}: Efficiency of the heat exchangers
- ρ : The ratio between the heat passed through thermoelectric materials to that passed from the hot side to the cold side.

2.4 Limitations

- High output resistance - in order to get a significant output voltage a very high Seebeck coefficient is needed (high V/°C). A common approach is to place many thermo-elements in series, causing the effective output resistance of a generator to be very high (>10Ω). Thus power is only efficiently transferred to loads with high resistance; power is otherwise lost across the output resistance. A generator with very high output impedance is effectively a temperature sensor, not a generator. This problem is solved in some commercial devices by putting more elements in parallel and fewer in series.
- Adverse thermal characteristics - because low thermal conductivity is required for a good thermoelectric generator, this can severely dampen the heat dissipation of such a device (i.e. thermoelectric generators serve as poor heat sinks). They are only economical when a high temperature (>200°C) can be used and when only small amounts of power are needed.

2.5 Advantages

- They 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.

2.6 DISADVANTAGES:

- The major drawback of thermoelectric power generator is their relatively low conversion efficiency up to 5 % only.
- Low availability.
- High cost.
- Low reliability.
- Chances of getting failed are more.
- Handling cost is more.

2.7 Electricity From Exhausts – Development Of Thermoelectric Generators For Use In Vehicles:

In the course of increasing demands to reduce fuel consumption and CO2 emissions of vehicles with combustion engines, we will have to make use of hitherto unused energy flows. It is well known that as much as a third of input energy is converted to exhaust heat, so it is clear that work needs to be done to increase the utilization of this energy. Through the application of thermoelectric generators (TEG), in the future a proportion of the energy carried by the exhaust gases that would previously have been lost will be recovered as electrical energy. The German Aerospace Center (DLR) has developed TEG for use in vehicles for doing this, and, resulting from collaboration with the BMW Group, 200 W of electrical power in a test vehicle was achieved in a demonstration. Given the use of future materials, performances of up to 600 W can be expected, yielding a usage potential of 5 %. The current research focus is aimed at improving the manufacturing technique with a view to future standard production applications.

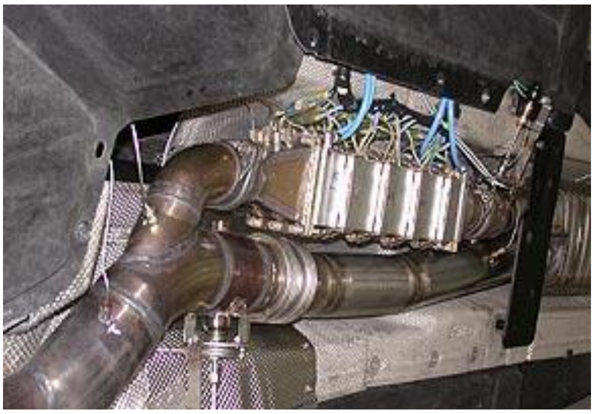

Fig. 3 - Automotive Thermoelectric Generator.

2.8 Automotive Thermoelectric Generator

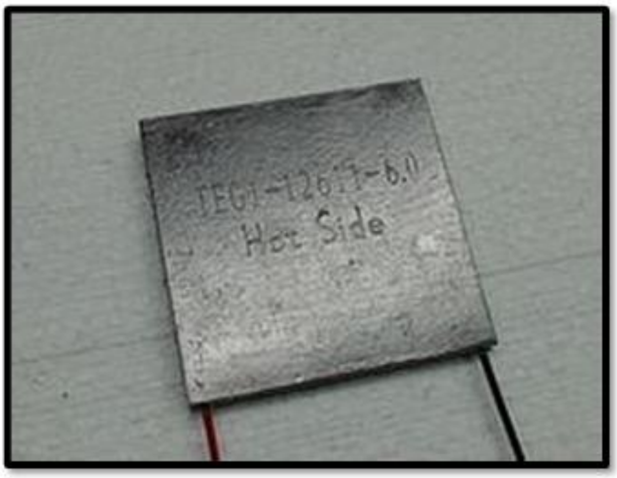

Fig 4: Automotive Thermoelectric Generator.

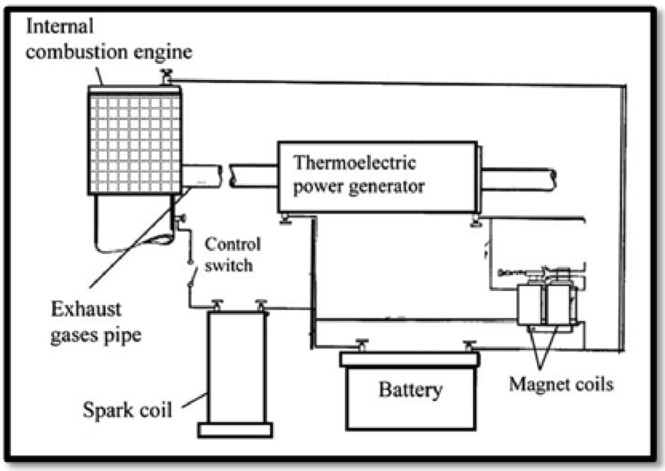

Fig 5: Schematic diagram showing early invention of converting waste heat into electrical power applied to an internal combustion engine using a thermoelectric power generator.

An automotive thermoelectric generator (ATEG) is a device that converts waste heat in an internal combustion engine (IC) into electricity using the Seebeck Effect. A typical ATEG consists of four main elements: A hot-side heat exchanger, a cold-side heat exchanger, thermoelectric materials, and a compression assembly system. ATEG can convert waste heat from an engine's coolant or exhaust into electricity. By reclaiming this otherwise lost energy, ATEGs decrease fuel consumed by the electric generator load on the engine. However, the cost of the unit and the extra fuel consumed due to its weight must be also considered. This could power the cars.

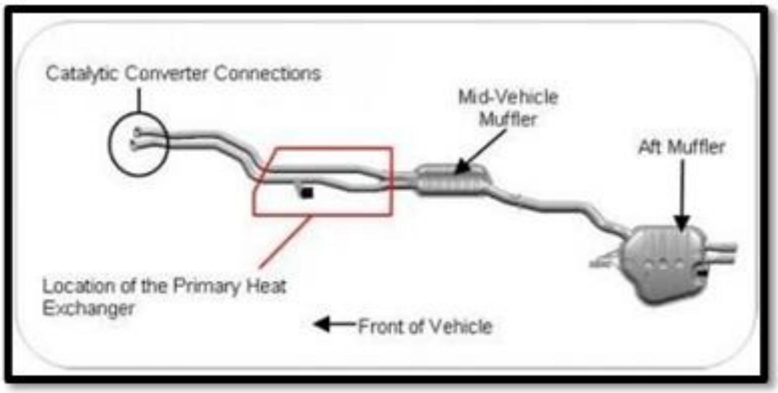

Fig 6: Automotive TEG.

2.9 Operation Principles

In ATEGs, thermoelectric materials are packed between the hot-side and the cold-side heat exchangers. The thermoelectric materials are made up of p-type and n-type semiconductors, while the heat exchangers are metal plates with high thermal conductivity. The temperature difference between the two surfaces of the thermoelectric module(s) generates electricity using the Seebeck Effect. When hot exhaust from the engine passes through an exhaust ATEG, the charge carriers of the semiconductors within the generator diffuse from the hot-side heat exchanger to the cold-side exchanger. The build-up of charge carriers results in a net charge, producing an electrostatic potential while the heat transfer drives a current. With exhaust temperatures of 700°C (~1300°F) or more, the temperature difference between exhaust gas on the hot side and coolant on the cold side is several hundred degrees. This temperature difference is capable of generating 500-750 W of electricity. The compression assembly system aims to decrease the thermal contact resistance between the thermoelectric module and the heat exchanger surfaces. In coolant-based ATEGs, the cold side heat exchanger uses engine coolant as the cooling fluid, while in exhaust-based ATEGs, the cold-side heat exchanger uses ambient air as the cooling fluid.

III. THERMOELECTRIC MATERIALS

Thermoelectric materials show the thermoelectric effect in a strong or convenient form. The thermoelectric effect refers to phenomena by which either a temperature difference creates an electric potential or an electric potential creates a temperature difference. These phenomena are known more specifically as the Seebeck effect (converting temperature to current).

Some of the materials used are Bismuth Telluride, Lead Telluride, Bismuth Chalcogenides, Inorganic Clathrates, Magnesium Group IV Compounds, Silicides, Skutterudite Thermoelectric, Oxide Thermoelectric, Half Heusler Alloys, Electrically Conducting Organic Materials, Silicon-Germanium, Sodium-Cobaltate, Functionally Graded Materials, Nonmaterial. Etc.

3.1 Application

Thermoelectric materials are applied for following purposes. a. Power generation.

b. Refrigeration.

IV. CONCLUSION

From this report it is understood that how important is the waste energy which is in the form of thermal energy. Also it is known that various components like thermoelectric generators, heat exchangers, thermoelectric materials, are put into operation to increase the efficiency. Also the researchers and scientists have been recovering for the inexpensive thermoelectric materials for the future. From this report it is understood the working, application, advantages, drawbacks, efficiency, of the thermoelectric generators and thermoelectric materials. It has been also concluded that by using this thermoelectric generators and materials could decrease the problems caused or related o automobile.

REFERENCE

1. Riffat SB, Ma X. Thermo electrics.
2. Rowe DM, Min G. Evaluation of thermoelectric modules for power generation manual.
3. http://www.ferrotec.com
4. http://www.customthermoelectric.com
5. Chen L, Li J, Sun F, Wu C. Performance optimization of a two stage semiconductor thermoelectric-generator. Appl Energy 2005; 82: 300-312.
6. www. Wikipidia.org
7. Darren quick's thermoelectric report.
8. D.M. Rowe, Int. J. Innovations Energy Syst. Power.
9. C. Vinning and D. M. Rowe, CRC Handbook of Thermo electrics.
10. D.M. Rowe, Renewable Energy 16, 1251.
11. D.T. Morelli, Proceedings of 15th International Conference on Thermoelectrics 1996.
12. T.J. Hendricks and J.A. Lustbader, Proceedings of 21st International Conference on Thermoelectrics (ICT) 2002.
13. ^ http://www.nature.com/nature/journal/v489/n7416/full/nature11439.html
14. ^ http://www.stealthpowersystems.com
15. ^ https://www.tegpower.com
16. ^ http://www.thermoelectric-generator.com/ultra_high_temperature_teg_power_modules.htm
17. Description of Thermoelectric Generators
18. Description of Automotive Thermoelectric Generators.

19. LT Journal October 2010: Ultralow Voltage Energy Harvester Uses Thermoelectric Generator for Battery-Free Wireless Sensors
20. Fairbanks, J., Thermoelectric Developments for Vehicular Applications, U.S. Department of