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A THERMOELECTRIC MODULE GENERATES ELECTRICITY FROM IC ENGINE EXHAUST THERMAL ENERGY

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ABSTRACT: The global problem of rising transportation costs is directly related to the increased use of internal combustion engines. The internal combustion engine has inadequate efficiency when it comes to converting chemical energy to mechanical energy. Thirty to forty percent of the thermal energy delivered by the fuel to the engine is converted into operating mechanical energy. Engine cooling systems and exhaust emissions release any residual thermal energy into the environment. Automobiles emit waste heat into the environment, which accounts for more than two-thirds of the energy consumed by the fuel. Thermoelectric generators are one technology that showed promise and performed admirably in this area. A thermoelectric module converts waste heat into electrical energy. The remaining heat from the exhaust manifold is transformed into electrical energy using a thermoelectric generator. Based on the test findings, it can be inferred that the proposed method efficiently recovers a significant amount of extra heat, which can be used to power several auxiliary vehicle systems.

Keywords: *IC engine, exhaust gas, heat energy recovery, heat transfer, thermoelectric generator, silencer.*

1. INTRODUCTION:

Automobile manufacturing is an important part of the economy. Up to 70% of the energy generated to heat by internal combustion engines used in automobiles is wasted. In recent years, scientists have worked tirelessly to develop automotive technology. However, their efforts to reduce heat loss in internal combustion engines have been limited. Internal combustion engines utilize the most fossil fuels worldwide. The engine converts around 30 to 40% of the heat energy supplied by the fuel into useable mechanical work. Exhaust gasses and engine cooling systems emit surplus heat into the environment. Petroleum-powered internal combustion engines can only use 30% of the heat they generate. The coolant causes 30% heat loss, with the remaining 40% dissipated as exhaust gasses. As a result, it is vital to find practical uses for the surplus heat. This differs dramatically from how residual heat is regulated in an internal combustion engine. The primary goal is to capture waste heat and transform it into power using a thermoelectric generator. A thermoelectric generator uses the Seebeck effect to transform thermal energy directly into electricity. The "Seebeck Effect" describes the method by which temperature differences are turned directly into electrical energy. A thermoelectric cell consists of two sides: warm and cool. Thermoelectric generators generate power by converting temperature differences across the module's reverse surfaces. These generators are environmentally beneficial, use waste heat, generate no noise, can operate as both heaters and coolers, are scaled up or down, silent, and have no moving components.

2. WORKING PRINCIPLE OF THERMO ELECTRIC GENERATOR

The temperature differential between two conductor connections generates an electromagnetic force (EMF). Thus, a closed cycle is formed. The phenomena represented in the image is known as the Seebeck effect.

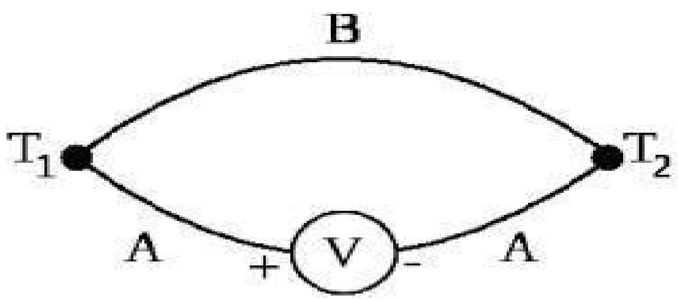

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Figure1: How Seebeck Behaved.

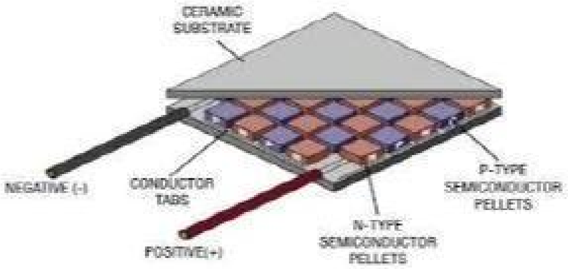

Figure2: A thermoelectric generator transfers heat energy into electrical power.

A thermoelectric pair is made of two granules of bismuth telluride (Bi2Te3), a semiconducting semiconductor. An acceptor impurity can be added to one of these pellets to transform it to a P-type pellet. A donor impurity can be introduced into the other pellet to form an N-type pellet. The two particles are placed externally between two clay plates in a thermoelectric generator. The plates give structural support while also preventing electricity from passing through them. In general, the pellets are connected on one side by a short copper strip. Figure 1 shows the assembly of semiconductor materials A and B to generate thermoelectric power. When thermal energy is transmitted between two thermoelectric pairs (T1 and T2) with a constant temperature difference, an electrical current called a Seebeck voltage is produced. When a resistive load is connected to the thermoelectric couple's output terminals, it generates an applied voltage (V). The reason for this is that electric current passes through the resistive load. To create operable thermoelectric modules, several thermoelectric couplings must be connected in parallel using both electrical and thermal energy.

3. LITERATURE REVIEW:

(1) MGJadhav,JSSidhu

The thermoelectric generators can be distinguished by the materials they are made of and the temperature ranges at which they function. Although many compounds have been recognized thus far, only a few of them have thermoelectric properties. The goal of this project is to develop an efficient way for harnessing the byproduct heat created by internal combustion engine exhausts. To attain this goal, an engine system must be devised and built. It has been determined that connecting two thermoelectric units in series allows for the following. The generated energy can be stored in the battery for later use or used immediately to power the vehicle's accessories. The exhaust pipe has no effect on the engine's performance or the functionality of the system that is designed to work with it.

Table1: **There are various types of thermoelectric engines.**

Sr no.	Thermo electric generator Materials	Temperature range
1.	Material based on Si-Ge alloys	Higher temperature upto1300K
2.	Materials based on all oys of Lead (Pb)	Intermediate temperature upto 850K
3.	Alloys based on Bismuth(Bi) in combinations with Antimony(An), Tellurium (Te) or Selenium (Se)	Low temperature upto 450K

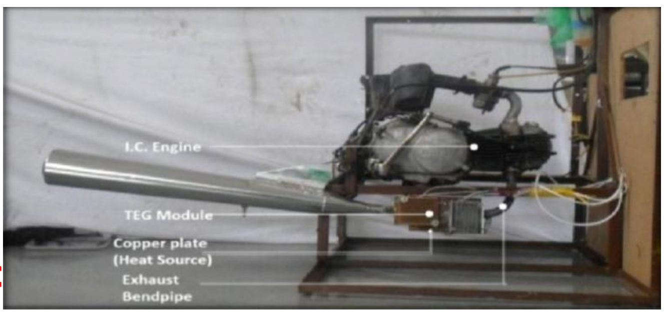

Figure 3The test environment for this investigation

(2)To connect the thermal electric generator, a 6 mm thick copper plate is mounted to the curved exhaust pipe of an internal combustion engine. A hot junction, consisting of a heated copper plate, sits atop a pair of thermoelectric generators that are linearly coupled. The metal cold sink is evident in contrast to the thermoelectric generators. Screws are used to connect thermoelectric generators at the hot and cold junctions, as shown in the diagram. Digital thermometers can be used to monitor both the hot and cold temperatures of the thermoelectric generator. By putting thermal sealant to the junction, the surfaces become more conductive, allowing heat to travel more freely.
B represents the second point. M. Mochizuki, Akbarzadeh Orr, and R. Singh wrote the piece. It is scalable, solid-state, inert, silent, and durable. These are characteristics that both heat pipelines and thermoelectric generators share. Heat lines can be used to reduce thermal resistance between gases and thermoelectric generators. Heat lines can minimize the surface area of the fins, lowering the pressure loss of the gas stream. Heat lines help keep the thermoelectric generator at the proper temperature. Thermoelectric generators have the following drawbacks: low efficiency and only operate at particular temperatures.
(3) The consistency of the modeling findings obtained from the mathematical model has been validated using experimental data. Under ideal conditions, the highest power production was obtained at 0.35 A and 0.43 W. The maximum power output measured at 511.3 W/m². Furthermore, the Seebeck effect showed that the output voltage rose as the temperature difference increased.
(4)The study's authors include Zeb, S.M. Ali, B. Khan, C.A. Mehmood, N. Tareen, W. Din, U. Farid, and A. Haidera, she explained. A capital "K."
Despite needing a significant initial investment, the thermoelectric generator's low operating costs allow for large-scale implementation. At present, thermoelectric generators are traded in a range of sectors.
These include the production of electricity for household and commercial use, refrigeration systems, biomedical, aerospace, military, automotive, clock, and remote applications. When thermoelectric generators are coupled in series and parallel, the module's voltage, current, and power output increases.

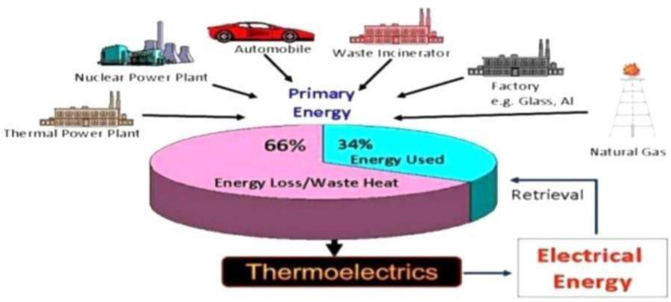

Figure4: Thermal-powered generators

(5)Chai-Cheng Hsu, Chun-hao Peng, Hsiao-kang Ma, How-Ping Wu, and Ching-Po Lin wrote the paper.
The thermoelectric generating system runs at a temperature difference of 150 to 505 K, with a maximum open voltage of 59 V. The gasifier's surface temperature varies from 473 to 633 K. This temperature range is used for recovering heat from waste. The machine's maximum output power at these temperatures is roughly 6.1 W. It delivers 193.1 W/m² of power in a tiny space. This study looks into potential applications for the byproduct heat produced by a biomass gasifier. It also investigates how to turn wood, which does not heat well, into a gaseous fuel that does heat well via the gasification process. According to empirical data, the gasifier's outlet temperature ranges from 623 to 773 Kelvin. A thermoelectric generator system (TEG) is attached to the cleaning surface of a catalytic reactor to maximize the use of excess heat.

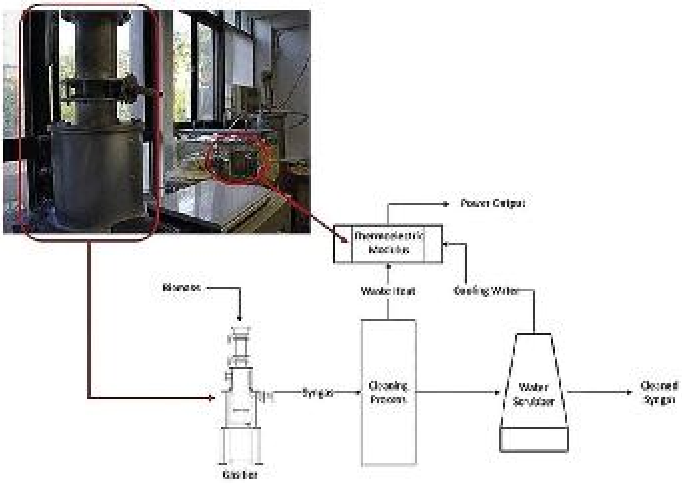

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Figure5: A diagram of the residual heat recovery system's design

(6)M.A. is a contributing author of the work. E.F. Thacher, B.T. Karri, and Thacher, P.T. The name Sheldon Brook.
The study examined whether quantum wells (QW) and bismuth-telluride (Bi_2 Te_1) thermoelectric power generation might power CNG engines and SUVs. In both instances, the quantum wells (QW) thermoelectric generator outperformed the bismuth-telluride (Bi_2 Te_0) generator. The fuel economy of the sports utility vehicle improves by about 0.2 percent with the Bi2Te3 engine and 1.25% with the QW engine. In the case of CNG, using Bi2Te3 reduced fuel use by around 0.4%. Using generators for the QW scenario reduced fuel use by approximately 3%.
(7)The power transfer rises in proportion to the temperature differential. The test findings show that the rectangle fin heat sink outperforms the circular tube fin heat sink in terms of heat transmission due to its design and capabilities. Choosing the right material for a thermoelectric generator's exhaust system is critical because it directly affects the generator's output power.

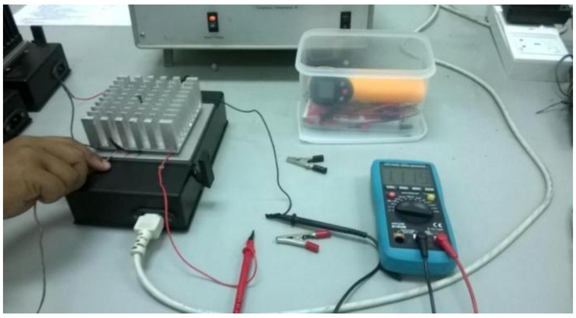

Figure6: A heat sink's temperature efficacy is investigated in conjunction with a thermoelectric generator.

(8) P. Shameer Ahmad and D. B. Christopher.
The goal is to convert remaining heat from the surface exhaust into usable electrical energy. This helps to avoid mishaps caused by overheated silencers. Connecting a large number of thermoelectric generators in series increases voltage and power, resulting in a higher output. This device provides power, which can be stored in a battery for later use or applied directly to automotive accessories..
(9) Alvin P. Koshy, Bijoy K. Jose, Jeffin Easo Johnson, K. Navaneeth Krishnan, and Bijeesh P. are mentioned in item 9.
This cutting-edge gadget boosts the engine's performance. The engine's output rises from 80 kW to 81.91895 kW at 4000 RPM. The heat efficacy increased from 37.3% to 38.19%. 5.28 g/kWhr has been removed from the BSFC
(10) J.S. Daghao and Jadhao were there. My beloved.
Significant energy savings can be achieved by using devices that recover heat from trash. This is the process of recovering and repurposing excess heat from an internal combustion engine for applications such as cooling, heating, and mechanical or electrical energy generation.

Table2**Different types of engines and their output levels.**

Sr. No.	Engine type	Power output kW	Waste heat
1	Small air cooled diesel Engine	35	30-40% of Energy Waste loss From I.C. Engine
2	Small agriculture tractors and Construction machines	150	
3	Water air cooled engine	35-150	
4	Earth moving machineries	520-720	
5	Marine applications	150-220	
6	Truck sand road engines	220	

(11) P.P. Harsha Vardhan and Prashanth, "M.V." signifies "motor vessel." and Venkatesha B. K. The heat energy emitted was collected by a thermoelectric generator, to which a booster circuit was later added to improve its strength. This method of power conversion is environmentally friendly because it does not utilize any moving parts or chemicals. By linking thermoelectric

generators in series, the voltage can be increased without the use of a booster circuit.
(12) Among the people listed is Z.B. Xie C. J. Tang, W.W. Shuai, and Y.D. Deng.
When the modules are joined in series, they lose significant power. Experiment results show that the modules' power is reduced by 11% from their theoretical maximum. Given the temperature discrepancy, this makes sense. Thermal insulation in the modules reduces temperature-related power loss to 2.3% under identical operating conditions.
(13) Only the letter "X" appears in the calligraphy. Y.D. Deng, C. Q. and Z. Li. Su. Because of the growing importance of environmental protection, extensive research has been conducted on thermoelectric technology. The transfer of an automobile's exhaust heat to a thermoelectric generator may provide an impressive 944 W of power. Improving the exhaust pipe will reduce thermal contact and raise temperature on the heated side, hence optimizing power generation. Further improvement could be accomplished in the assembly of the components. For the next generation of prototype autos, optimization design, energy conversion efficiency, and system power capacity are all crucial.
(14) To create heat, Eid S. Mohamed fitted a TEG system to the exhaust pipe of a tiny diesel vehicle. To dissipate heat, a computational fluid dynamics (CFD) model was used to examine the airflow around the cool side of the thermoelectric generator (TEG). As engine speed increases, so do the temperatures of the waste gasses. At 3750 revolutions per minute, the input temperature of 340°C is converted to an output temperature of 300°C. The velocity of the vehicle's engine is inextricably related to the output power of the thermoelectric generator (TEG). The highest power that the TEG can generate at 3750 revolutions per minute (rpm) is roughly 214 W. According to the results of a series of trials, activating a thermoelectric producing system reduces the amount of exhaust gas released.
(15) Tyler J. Meehan and Alexander S. Rattner discussed the strategic issues required in implementing a specific waste heat recovery system on a modest scale. Within this system, the individual thermoelectric generator units are organized in a linear pattern. Heat is transported to longer surfaces by conductive heat spreaders using heating and cooling streams that travel in the same direction. A conventional vehicle waste heat recovery system was designed and tested using the proposed technology. The figure below shows how to build a device that recovers extra heat using the model. It required calculating the ideal number of thermoelectric generator units, as well as the principal barriers to their power generation.
(16) For this study, we built models using a thermoelectric generator system placed in a conventional automobile to analyze engine power and relative power. Furthermore, an energy efficiency factor was used to calculate how much energy a thermoelectric generator system could extract from medium-duty, heavy-duty, and light-duty conventional autos. The theoretical model's knowledge serves as the foundation for the conclusions.
(1) The discharge rate and temperature of the exhaust have a considerable impact on the power output of a thermoelectric generator.
(2) When placing a thermoelectric generator in a heavy-duty vehicle, blow-down loss must be considered. The thermoelectric generator for a light-duty vehicle should be as compact as possible. (3) For the purposes of this research, the thermoelectric generator should be predominantly deployed on a heavy-duty vehicle going at less than 100 km/h.
(17) A thermoelectric device with a flow is known as an integrated thermoelectric device. It is made up of p- and n-type semiconductor plates that are bonded to a highly conductive substance. The device's performance was tested using numerical models. It is made up of several components that are thermally and electrically coupled in series and parallel.
(18) This article describes a unique method for producing energy from the waste of internal combustion engines. The procedure is based on the use of automotive coolant and fumes. The coolant waste energy collecting mechanism provides heated air to the engine at temperatures ranging from 60 to 70 degrees Celsius, thereby commencing the heating process. This happens when the fuel in the barrel is spent, which is advantageous. The waste energy collection solution for the exhaust system was designed using an inaccurate intelligently controlled Micro-Faucet emission gas recirculation and a thermoelectric generator. To increase brake performance and reduce emissions, more control must be exerted over fuel atomization, dissolution, and heat transmission within the chamber.
(19) The purpose of this study is to present a comprehensive account of the most recent breakthroughs in the applications of thermoelectric producing units. Lauri Kütta, John Millar, Antti Karttunen, Matti Lehtonen, and Maarit Karppinen wrote this review. This study will conduct a thorough examination of the important components needed for the analysis of a thermoelectric generator system. Special emphasis will be made on the valuable results obtained from testing the experimental systems in this study. There are two parts to the review. The first section discusses the essential components and operation of thermoelectric generators. The power electronic converters that make up the generators' loading mechanism are also described. The second section focuses on the use of thermoelectric generators in biomass burners and residential boilers. The second half of the study paper will present an outline of solar energy applications in thermoelectric generators. The thermoelectric generator turns heat energy into electrical energy.

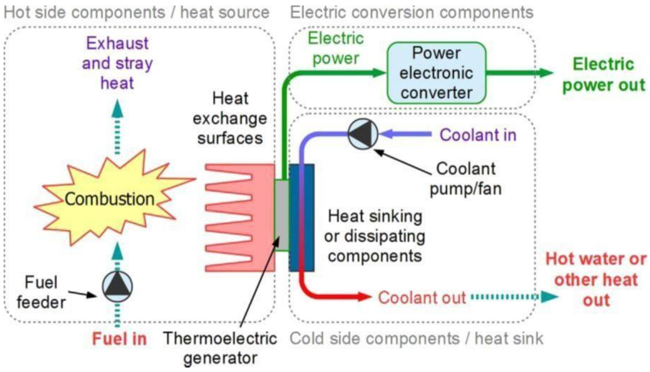

Figure7: The configuration of a thermoelectric conversion device that works through combustion.

Peltier elements were explored in the study by Norbert Stuban and Adam Torok because they are simple to install in the exhaust system. The authors discovered a direct association between resistance (measured in ohms) and voltage (measured in volts) by studying a corpus of worldwide literature currently being published. It is critical that the Peltier element has a finite power output and that the voltage is controlled by Seebeck. The author's calculations show that a thermocouple with a theoretical capacity of 50 W and a temperature difference of 87 °C may generate 1.2 W of electricity

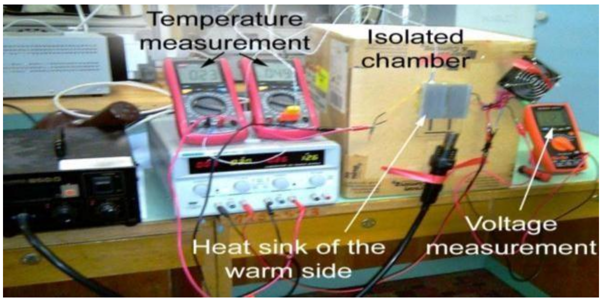

Figure8: Conducting an experiment where the voltage across the Peltier element is measured at various temperatures.

4. CONCLUSION:

In order to study various techniques of power generation, we performed a thorough analysis and simulation of a thermoelectric module. The process generates a significant electrical potential using a meticulously designed structure. A thermoelectric module can generate a small amount of electrical current as long as the temperature difference between its two terminals is constant. The highest voltage was created at the biggest temperature difference.

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