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Study of Waste Heat Recovery in the Form of Electricity from Engine Exhaust

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ABSTRACT

The current worldwide trend of increasing transportation is responsible for increasing the use of internal combustion engines. I.C engines, the devices with a high energy usage and low efficiency because roughly 75 % of the energy produced during combustion is lost in the exhaust and in the coolant of the engine in the form of heat. Energy crisis and thermal energy management are the critical topics of present scenario. As we know that a major part of the heat supplied in an internal combustion engine is not converted into useful energy, but dumped into the atmosphere as waste heat so it becomes necessary to recover this waste heat. Thermoelectric modules are solid state devices that are used to convert thermal energy from a temperature gradient to electrical energy. This temperature difference can be obtained from exhaust gas pipe, as outer surface of the exhaust pipe of engines can reach the temperature up to 200^0C to 400^0C when exhaust gases are flowing through it. As a huge amount of energy is lost, there is urgent need to design a advice to trap this loss. In this paper a attempt is made for the implementation of waste heat recovery system using a thermoelectric generator (TEG) designed for automobile engine. There are various technique and designs adopted for waste heat recovery from an automobile sector. In this way we can say that thermoelectric generators may play an important role in enhancing the overall efficiency of an internal combustion engine as they help in tapping and converting waste heat energy from exhaust into usable energy. This same concept can be implemented on big scale for waste heat recovery so that to achieve development through green technology.

Keywords— Thermoelectric module, Seebeck effect, Heat of exhaust gases, Temperature difference, Waste Heat Recovery.

INTRODUCTION

The automotive industry is one of the most important economic sectors in the world. Cars use IC engines, which have a significant loss of power up to 70% in the form of heat. In more recent times, scientists have tried and experimented with automotive technology with ease, but have been unable to control the loss of an IC engine in the form of waste heaters. This paper focuses primarily on regulating the heat of the IC engine waste, instead focusing on capturing waste heat to generate electricity using a suitable thermoelectric generator (TEG).

The conversion of temperature difference to electric current and vice versa is called the thermoelectric effect. In 1981, Thomas Johann Seebeck discovered that a region with two different metals with different temperatures could divert a compass magnet. He saw that there was an electric current being drawn, which by the law of Ampere distorted the magnet. Also the electric current or electric current due to temperature differences can drive the electric current in a closed circuit.

To measure these voltages, one has to use a second device that produces different electrical power under the same temperature gradient. Alternatively, if the same device is used for measurement, the electrical output generated by the measuring operator may simply be canceled by the first conductor. The power difference generated by two objects can be measured and is related to the corresponding temperature gradient. It is therefore clear that, based on Seebeck’s policy; thermocouples can only measure temperature differences and require a known reference temperature to provide a complete reading.

The principle behind it is

V- Voltage difference between two dissimilar metals

a- Seebeck coefficient

T_h - T_c - Temperature difference between hot and cold junctions

There are three major effects involved in the thermocouple circuit: the effects of Seebeck, Peltier, and Thomson.

Seebeck effect describes the voltage or electromotive power (EMF) caused by the temperature difference (gradient) along the fence. The conversion of EMF material in relation to temperature change is called Seebeck coefficient or thermoelectric sensitivity. This coefficient is usually a non-linear temperature function.

TEG Types:

Thermoelectric production materials and there are temperatures as follows. There are a number of consumer goods to date but few are identified as consumer goods.

Sr. No.	**TEG Materials**	**Temperature range**
1	Material based on Si-Ge alloys	Higher temperature upto1300K
2	Materials based on alloys of Lead (Pb)	Intermediate temperature up to 850K
3	Alloys based on Bismuth (Bi) in combinations with Antimony(An), Tellurium (Te) or Selenium (Se)	Low temperature up to 450K

LITERATURE SURVEY

Akash Pandey et al. [2021] The purpose of this current paper is to present a summary of the various studies designed to achieve thermal uniformity, heat transfer rate, and AXEG pressure reduction indicators for AETEG. Future ideas of good heat exchange designs are also proposed that could improve the rate of heat recovery from engine exhaustion.

Hanlin Cheng et al. [2020] This paper shows significant advances in thermal harvesting by the development of hybrid ionic / electronic thermoelectric converter (HTEC). The device consists of an electronic unit and an ionic unit. The electronic unit is made of thermoelectric polymer, poly (3,4-ethylenedioxythiophene): poly (styrene sulfonate) (PEDOT: PSS), and ionic unit is made of ionogel. In addition to the conversion of heat to electricity by the electronic unit from the heating core due to the Seebeck effect, the ionic unit can generate electricity from temperature fluctuations due to thermal ionic diffusion (Soret effect). Energy production can be several times higher than a thermoelectric generator using PEDOT: PSS. Because waste heat temperatures are often variable, HTECs can increase the conversion of very high heat to electric energy than conventional thermoelectric generators with only electronic conductors.

UB Jiang et al. [2020] Here, we show that we can significantly reduce the lattice transmission of n-type PbS-based material to 0.4 W m-1 K-1 by introducing zigzag nano bars with a similar diameter around 1 nm. Electron flow was also successfully enhanced by reducing the active size using Se alloying. Finally, an odd statistical value of 1.7 to 900 K was obtained from the sample of n-type $Pb_{0.93}Sb_{0.05}S_{0.5}Se_{0.5}$. The thermoelectric power generation module is built with this n-type PbS and our p-type PbTe made with high performance. It showed a high efficiency of 8.0% with a temperature difference of 565 K. In addition, a separate module containing in- / p-Bi2Te3 and n-PbS / p-PbTe was made, showing a high efficiency of 11.2% with a temperature difference of 585 K. This same functionality is similar to the reported PbTe modules, and was recognized at a much lower cost. As a result, low-performance n-type PbS-based products as a promising PbTe alternative will promote the wide commercial application of thermoelectric power generation.

Mohamed Amine Zoui et al. [2020] In this review, generators of state-of-the-art thermoelectric technologies, applications and recent advances are reported. Basic information on thermoelectric effect, basic rules, and parameters affecting the effectiveness of common and new thermoelectric materials is discussed. Thermoelectricity applications are organized into three main domains. The first group deals with the use of heat emitted from radioisotope to supply electricity to various devices. In this group, space exploration was the only application in which thermoelectricity was successful. In the second group, a natural heat source may appear to be useful in generating electricity, but since thermoelectricity is still in the first stage due to the conversion efficiency, applications are at a laboratory level. The third group is moving ahead at an alarming rate, largely because the investigation is funded by governments and / or car manufacturers, with the ultimate goal of reducing fuel consumption and ultimately reducing the impact of greenhouse gas emissions.

Ragupathi et al. [2020] The current research work focuses on generating electricity from thermal energy that is distributed by hot gas (BEG) internal combustion engine (IC). A horizontal pass straight duct (HTSPD) temperature (HE) with thermoelectric generator (TEG) was used to obtain power. The HTSPD HE model was developed, developed and investigated by testing the potential for power generation in relation to TEG.

U Nesrine Jaziri et al. [2019] This paper introduces an in-depth analysis of TEGs, starting with a detailed description of their operating principles, types (planetary, vertical and mixed), materials used, value qualifications, development strategies that include the arrangement of different thermoelectric properties (standard, isolated and cascaded), and the technology used and the types of substrates (silicon, ceramics and polymers). This document also describes the exploitation of TEGs in a variety of fields from low-power applications (medical and wearable devices, IoT: internet of things, and WSN: wireless network) to high-power applications (industrial electronics, automotive engines, and aerospace)

L.S. Hewawasam et al. [2019] This paper study was designed to understand the possibility of combining TEG with engine muffler, without disrupting the performance of the muffler to reverse the waste heat of the engine exhaust system. The findings of the study show that thermo-electric modules (TEMs) can be easily integrated into a muffler and that electricity can be easily utilized using the output power available from the exhaust hot power.

Murat EmreDemir et al. [2017] The waste recycling system (WHR) is designed to be available after a recycling vehicle recycling and recycling process, and consists of a shell and a thermal shell to heat its pipes covered with electrical wiring. Three different Perovskite-type oxide composites of thermoelectric materials ($CaMn_{0.98}Nb_{0.02}O_3$, $La_{1.98}Sr_{0.02}CuO_4$ and $GdCo_{0.95}Ni0_{.05}O_3$) were selected, selected and mathematically selected. Variations in physical properties, efficiency and energy output in relation to temperature and condition are set.

Hassan Fagehi et al. [2016], In this work, analytical models have been developed to calculate the performance of a thermoelectric generator system and test validation. The first part of this concept is about the analytical model, using positive statistics in which communication resistance is included. The model was used to validate the module testing conducted by GM, which showed good agreement. Therefore, the effect of leg length and materials on ceramic plates was investigated. Based on the concept of leg length and ceramic plate materials and the improvement of hot and cold side temperature, the new design is introduced with a significant improvement in density compared to the textbooks.

Tzer-Ming Jeng et al. [2016] This study combined techniques for high-performance heat transfer and thermoelectric modification to form a thermoelectric generator system installed in a single-cylinder exhaust pipe and a single stroke of 35.8 c.c. migration. The system is made up of a heat absorber, thermoelectric generator modules and an external heat sink. A pin-fin array was inserted into the rotating shaft to form a heat absorber, which could increase the heat exchange and heat exchange time to reach the heat absorber and increase thermoelectric conversion effectively

Aravind Karuppaiah et al. [2014] The project describes the construction and analysis of TEG materials used. A study of factors affecting TEG performance is studied. Item features, TEG efficiency and heat transfer to TEG are also studied using BOOKS

Ajay Chandravanshi et al. [2013] developed their project using only four thermoelectric modules by keeping temperatures higher than these modules at different temperatures.

T Stephen John [2013] studied High Efficiency Seebeck Thermoelectric Device for Power System Design and Efficiency Calculation. The House of Commons Review has a Mission. Here Bismuth telluride material is used and it is found that the thermoelectric power produced is more than 2.5 watt DC per TEG, which is economically attractive.

P. Mohamed Shameer et al. [2013] in his paper he had successfully produced a gas-fired emission gas. He had installed the Peltier module directly on the test bike silencer and had also used the Booster circuit to increase the output power.

R. Saidur et. al. [2013] studied in Technologies to rediscover the heat emitted by internal combustion engines. The study also revealed the power of technology when combined with other devices to increase the efficiency of vehicles. It should be noted that TEG technology can be combined with other technologies such as PV, turbocharger or Rankine bottle cycle process to increase energy efficiency, reduce fuel consumption and greenhouse gas (GHG) emissions.

CONCLUSION

From the above discussion we found that Thermoelectric generators (TEGs) have demonstrated their ability to directly convert thermal energy into an electrical one via the Seebeck effect. Also, they are environmentally friendly because they do not contain chemical products, they operate silently because they do not have mechanical structures and/or moving parts, and they can be fabricated on many types of substrates like silicon, polymers, and ceramics. Furthermore, TEGs are position-independent, present a long operating lifetime and are suitable for integration into bulk and flexible devices.

The small amount of electricity generated are utilized for various means in a vehicle for the functioning of other devices.

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