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Thermoelectric Cooling from Exhaust Gas Manifold

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ABSTRACT: This project implements a structured system analysis and design methodology of an experimental setup to provide a cooling system which functions using a thermoelectric cooling device, for which a part of power is generated from the heat energy of the exhaust gas using thermoelectric generator. The main functional part of our project is Thermoelectric device. Two types of thermoelectric devices viz. Thermoelectric cooler and Thermoelectric generator are combined to produce output of the entire system. In this project both the cooling and power generating devices are combined to produce a closed system. The input of the cooling devices is obtained from the output of the power generating thermoelectric device, where its input is obtained from the heat energy of the waste exhaust gas from the automobile.

I. INTRODUCTION

A conventional cooling system (HVAC) basically cools a space by removing the heat from the stipulated region using refrigerants like HFC and CFC. This system is very efficient but has many demerits.The refrigerants used in HVAC pollute the ozone layer and increases global temperature. If this system prevails, the rate of depletion of ozone will be continuously increasing and the penetration of harmful rays into the earth becomes more.
There is a need to find an effective alternative for HVAC system, for which Thermoelectric modules are deployed.Thermoelectric devices are not much used practically. But it holds many advantages with wide range of applications. These devices hold a major impact in the modern and innovative thermal system.
In this project both the cooling and power generating devices are combined to produce a closed system. The input of the cooling devices is obtained from the output of the power generating thermoelectric device, where its input is obtained from the heat energy of the waste exhaust gas from the automobile.

A. *Working Principle*

The principles of thermoelectric cooling and thermoelectric generator are :

a) Peltier effect

b) Seebeck effect

THERMOELECTRIC COOLING :

A thermoelectric (TE) cooler, sometimes called a thermoelectric module or Peltier cooler, is a semiconductor-based electronic component that functions as a small heat pump. By applying a low voltage DC power source to a TE module, heat will be moved through the module from one side to the other. One module face, therefore, will be cooled while the opposite face simultaneously is heated. It is important to note that this phenomenon may be reversed whereby a change in the polarity (plus and minus) of the applied DC voltage will cause heat to be moved in the opposite direction. Consequently, a thermoelectric module may be used for both heating and cooling thereby making it highly suitable for precise temperature control applications.
To provide the new user with a general idea of a thermoelectric cooler's capabilities, it might be helpful to offer this example. If a typical single-stage thermoelectric module was placed on a heat sink that was maintained at room temperature and the module was then connected to a suitable battery or other DC power source, the "cold" side of the module would cool down at a good rate. At this point, the module would be pumping almost no heat and would have reached its maximum rated "DeltaT (DT)." If heat was gradually added to the module's cold side, the cold side

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temperature would increase progressively until it eventually equaled the heat sink temperature. At this point the TE cooler would have attained its maximum rated "heat pumping capacity" (Qmax). Both thermoelectric coolers and mechanical refrigerators are governed by the same fundamental laws of thermodynamics and both refrigeration systems, although considerably different in form, function in accordance with the same principles.

The application of DC power to the thermoelectric module causes electrons to move through the semiconductor material. At the cold end (or "freezer side") of the semiconductor material, heat is absorbed by the electron movement, moved through the material, and expelled at the hot end. Since the hot end of the material is physically attached to a heat sink, the heat is passed from the material to the heat sink and then, in turn, transferred to the environment.The physical principles upon which modern thermoelectric coolers are based actually date back to the early 1800's, although commercial TE modules were not available until almost 1960. A French watchmaker and part time physicist, Jean Peltier, while investigating the "Seebeck Effect," found that there was an opposite phenomenon whereby thermal energy could be absorbed at one dissimilar metal junction and discharged at the other junction when an electric current flowed within the closed circuit. Twenty years later, William Thomson (eventually known as Lord Kelvin) issued a comprehensive explanation of the Seebeck and Peltier Effects and described their interrelationship. At the time, however, these phenomena were still considered to be mere laboratory curiosities and were without practical application.

In the 1930's Russian scientists began studying some of the earlier thermoelectric work in an effort to construct power generators for use at remote locations throughout the country. This Russian interest in thermoelectricity eventually caught the attention of the rest of the world and inspired the development of practical thermoelectric modules. Today's thermoelectric coolers make use of modern semiconductor technology whereby doped semiconductor material takes the place of dissimilar metals used in early thermoelectric experiments.The Seebeck, Peltier, and Thomson Effects, together with several other phenomena, form the basis of functional thermoelectric modules.

II. LITERATURE REVIEW

Dr. Steven O'Halloran, University of Portland[2012] documents a laboratory experiment to determine the efficiency of a commercial thermoelectric generator. Thermoelectric devices make use of the Seebeck effect to convert a difference in temperature into electricity. Thermoelectric devices are used or proposed for a number of different current applications including waste heat recovery. In the experiment, a LabVIEW data acquisition system measures real-time efficiency of the thermoelectric device under different testing conditions. The experiment is well-suited for an undergraduate thermal sciences lab or a demonstration for a thermodynamics lecture course.

K.T. Zorbas, E. Hatzikraniotis, and K.M. Paraskevopoulos documents that Thermoelectric generators (TEG) make use of the Seebeck effect in semiconductors for the direct conversion of heat into electrical energy, which is of particular interest for high reliability systems or for waste heat recovery. The generator efficiency, η, is determined by comparing the amount of electricity produced (Pout) to the total amount of heat induced (Qin). A measuring system and a modelling approach which takes into account the thermal contact resistances have been developed, allowing the characterization of TEG devices under various loads and temperature gradients and thus, to evaluate material properties. These results were used to identify the appropriate positions at the exhaust pipe of a midsize vehicle for the optimum recovery of the wasted heat using a commercial TEG and to establish a set of requirements for an automotive TE waste heat recovery subsystem.

Manoj S. Raut and Dr.P. V. Walkedescribes that, Today's present HVAC system is very efficient and reliable but it has some demerits. It has been observed during the last two decades that the O3–layer is slowly destroyed because of the refrigerant (CFC and HFC) used for the refrigeration and air – conditioning purposes. The common refrigerant used is HFC's which are leaked and slowly climb into the atmosphere. When they reach to O3 layer they act on O3 – molecules and the layer of O3 is destroyed. A single molecule of HFC's can destroy thousand of O3 molecules and that's why it has created a threat for the not only to maintain earth eco system stable but also to existence of earth The capacity of HFC's to increase in earth temperature 10% is contributed by HFC's only.

Thermoelectric cooling can be considered as one of the major applications of thermoelectric modules (TEM) or thermoelectric coolers (TEC). The main objective of this project is to design a cooling system installed on a conventional blower of car AC.The idea of cooling is based on Peltier effect, as when a dc current flows through TE

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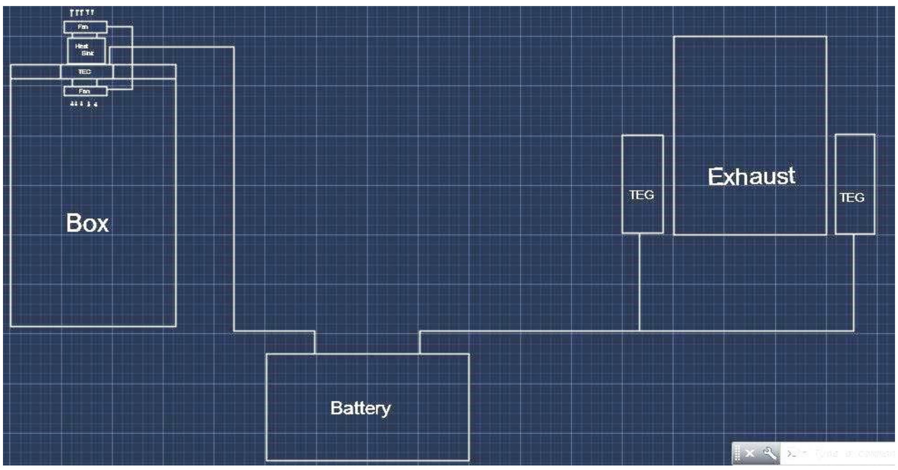
modules it generates a heat transfer and temperature difference across the ceramic substrates causing one side of the module to be cold and the other side to be hot. The purpose of the project is to make use of the cold side to cool the ambient air to a lower temperature, so that it can be used as a personal cooler. A simple temperature controller to interface with the cooling system has also been incorporated. Based on an analysis of sizing and design of the TEC air cooling for car, it can be deduced that the cooling system is indeed feasible.

Gang Tan ,Dongliang Zhaostudied thata thermoelectric cooling system integrated with phase change material (PCM) has been proposed for space cooling purpose, in which PCM stores cold thermal energy at night and functions as a heat sink to reduce hot side temperature of thermoelectric modules during daytime cooling period and thus improve the performance efficiency of the system. A numerical model for the PCM-integrated thermoelectric cooling system has been developed to analyse the entire system under two working modes: (1) dissipating the generated heat directly to outdoor air through the air water heat exchanger (mode 1) and (2) releasing heat to the shell-and-tube PCM heat storage unit (mode 2).
Experimental tests showed the average system cooling COP is increased by 56% (from 0.5 to 0.78) because of PCM integration. With the experiment validated numerical modelling, a comprehensive guide of the design procedure for the PCM integrated thermoelectric space cooling system has been introduced. The thermoelectric cooling system is designed, as a case study, for an office room located in Denver, Colorado, from which two conclusions have been made: (1) the cooling power output, COP and cost are the most important three factors that determine the selection of thermoelectric modules (TEM) from market available products and (2) the accumulated heat dissipation of the cooling system determines the volume of PCM while local weather condition also needs to be evaluated to ensure PCM will be fully discharged at night.

III. METHODOLOGY

3.1 Design of Experiments:

A TEG setup is made by pasting TEG modules in two different plates which are inclined to each other by 25-30 deg.This is then connected to a battery so that the power generated is stored, and then utilized for running the TEC modules. Now the engine is started and the heat from the manifold comes in contact with the TEG, current is generated and this is stored in the battery and this energy is then utilized by the TEC which in turn provides cooling effect by producing two junctions viz., hot and a cold.The heat from the hot junction is sucked out by a fan so that it could be dissipated to the atmosphere and the other side has a good cooling effect which is utilized to produce the cooling effect inside the cooling box.



Construction design

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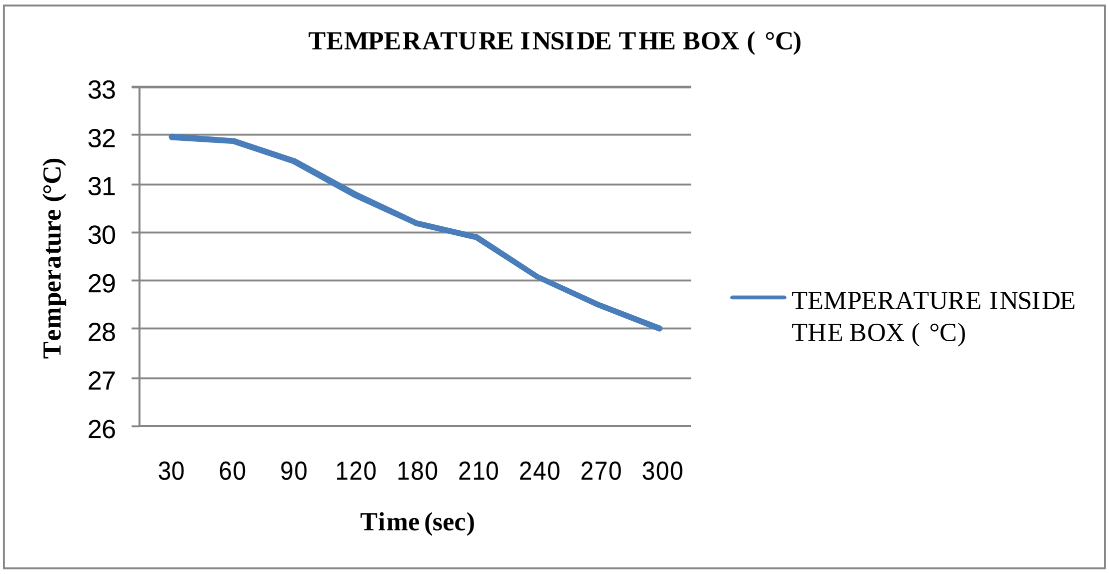
IV. RESULT AND DISCUSSION

The obtained readings have been tabulated and corresponding graphs are drawn to analyse the output of the system.

Tabulation for TEC

TIME (sec)	TEMPERATURE INSIDE THE BOX(°C)
30	32
60	31.9
90	31.5
120	30.8
180	30.2
210	29.9
240	29.1
270	28.5
300	28

TEC - Graph



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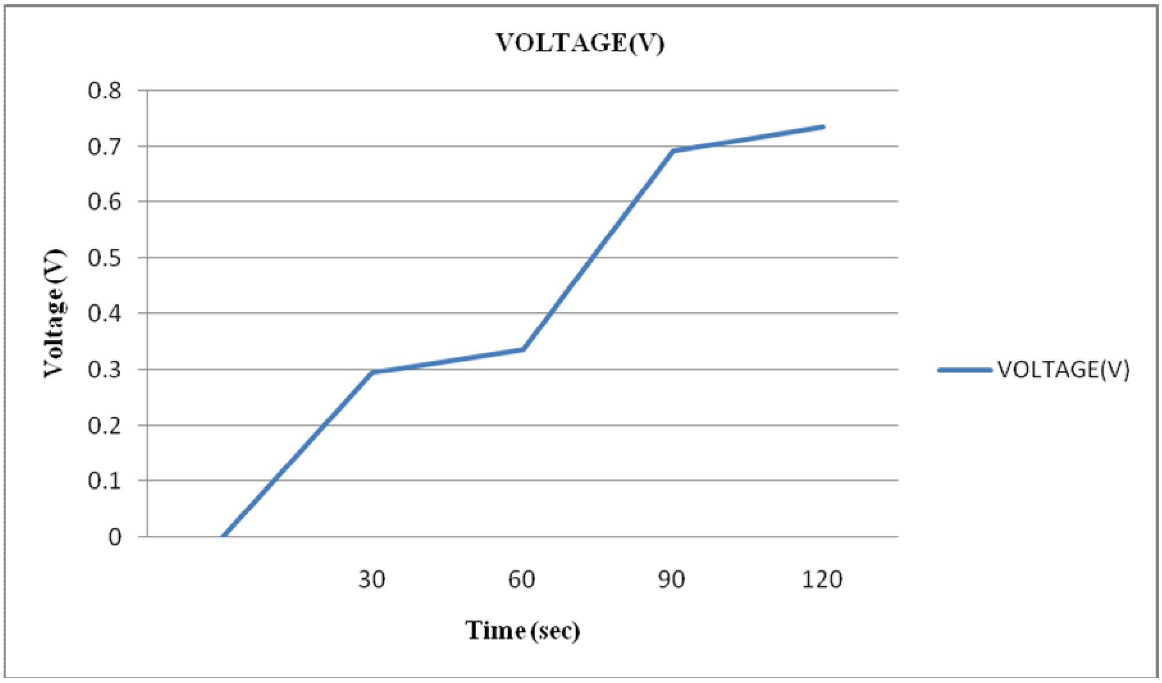
Tabulation for TEG

TIME (sec)	VOLTAGE (V) volt
30	0.296
60	0.337
90	0.693
120	0.736

TEG - Graph



We observe from the graph,
TEC **-** The temperature inside the box decreases with the increase in time as the thermoelectric module is made to cool with continuous power supply.
TEG – The voltage that is being generated increases with the increase in time, as the temperature of the exhaust gas manifold increases.

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V. CONCLUSION

The usage of harmful refrigerant (CFC and HFC), which are used for refrigeration and air – conditioning purposes can be avoided. Harmless working source for the cooling system is found. A simple and less economic cooling system is designed. Waste heat energy of the exhaust gas is utilized to generate electricity. Unused exhaust gas is utilized to produce an electrical output. Thus thermoelectric devices can be used as a source for cooling system in automobiles so that the emission of toxic gases from the refrigerants to the environment can be avoided.
Our project gives a small cooling device which functions as same as the proposed thermoelectric principles. Bigger heat sink has to be selected accurately based on the calculated thermal resistances for best cooling And this system can be simply extended to the required size so as to supply complete cooling effect in an automobile, so that it could replace the existing HVAC system.

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