Designing and Testing the Optimum Design of Thermoelectric Air Conditioner for Automobile

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Abstract— According to International Institute of Refrigeration, air conditioning and refrigeration consumes around 15% of the total worldwide electricity and also contributes to the emission of CFCs, HCFCs, CO_2 etc. Due to the use of such refrigerants it leads to much harmful effect to our environment i.e. the global warming. For air conditioning use of fuel also increases and all these are affect on the car efficiency. To overcome the problem of emission and fulfill the mismatch between the demand and supply of energy consumption the thermoelectric Air conditioning can be used. This system is not going to be noisy, a there will be no hazardous emission to the environment so the system is totally ecofriendly. As the Peltier module is quite compact in size the design can be easily acquired according to space and need.

Keywords: Thermoelectric Air Conditioner, HVAC, CFC

I. Introduction

A thermoelectric module is an electrical module, which produces a temperature difference with current flow. The emergence of the temperature difference is depending on the Peltier effect designated after Jean Peltier. The thermoelectric module is a heat pump and has similar function as a refrigerator. It gets along however without mechanically small construction units (pump, compressor) and without cooling fluids. The heat flow can be turned by reversal of the direction of current. Thermoelectric cooling provides an alternative solution to the common compressor and absorber cooler. Thermoelectric coolers are used especially if small cooling power is required up to 500 W.

Our goal is to define the new HVAC system using thermoelectric couple which shall overcome all the drawback of current HVAC system. If this system comes in present HVAC system, then revolution will occur in the automobile. With rising population and pollution at an alarming rate this system has come to rescue as these are environment friendly and compact. Conventional compressor run cooling equipment have more limitations related to energy efficiency and Chloro-Fluro Carbon (CFC) refrigerants use. Both these factors indirectly point to the impending scenario of global warming. As most of the electricity generation relies on the coal power plants, which add greenhouse gases to the atmosphere is the more cause of global warming. Although researches are going on, best alternatives for the CFC refrigerants is still on the hunt. So instead of using conventional air conditioning systems, other products which can efficiently cool a person are to be planned. By using other efficient cooling device, we can save the electricity bills as well as control the greenhouse gases that are currently released into the surrounding atmosphere.

Although thermoelectric property was discovered about two centuries ago thermoelectric device save only been commercialized during current years. The applications of thermoelectric vary from small refrigerator.

II. Problem Statement

In car air conditioning system is used for cooling purpose. The problem associated with it increases the fuel consumption and causes Environmental problem. Also the efficiency of vehicle gets affected

To overcome the problem we develop new system in car. We use exhaust gas heating medium for the thermoelectric module and it generate electricity which is stores in the battery. Then this electricity pass to peltier plate and due to this peltier plate giving cold medium on its one side. Thus cooling effect will be produced.

A. Objectives

1) To develop Eco friendly system

According to International Institute of Refrigeration, air conditioning and refrigeration consumes around 15% of the total worldwide electricity and also contributes to the emission of CFCs, HCFCs, CO_2 .etc. Due to the use of such refrigerants it leads to much harmful effect to our environment i.e. the global warming.

We use exhaust gas heating medium for the thermoelectric module and it generate electricity which is stores in the battery. Then this electricity passes to peltier plate and due to this peltier plate giving cold medium on its one side. Thus cooling effect will be produced. And develop eco-friendly system.

1) To increases in Car Efficiency: For air conditioning system use of fuel also increases and increasing fuel consumption decreases in car efficiency and also the compressor used in AC system which is drive on the engine compressor because of this this affect on car efficiency. To overcome this problem we develop thermoelectric air conditioning system. This system uses increases in car efficiency.
2) To Develop Cost Effective System: In conventional air conditioning system we use compressor, condenser, expansion valve and evaporator.so costing of this system also high. And maintenance of system also adds cost. That's why use thermoelectric AC which reduce the total cost of this system and develop coat effective system
3) To study critically existing HVAC system for its advantage and disadvantages. To explore various technological option to replace existing HVAC system. And study TEC as a substitute for present HVAC system which will overcomes the all demerits of present HVAC system.
4) To fabricate working model of HVAC using TEC. To test HVAC using TEC for its effectiveness, efficiency, environment friendliness, comfort and convenience

B. Scope

Air conditioning is a process of removing heat from a space or other applications. Many ways of producing a cooling effect by like vapour compression and vapour absorption air condition. In car air conditioning system is used for cooling purpose. The air-conditioning system produces cooling effect by refrigerants like R134, R12, etc. Using these refrigerants can get maximum output but one of the major disadvantages is harmful gas emission and global warming. The operation of AC increases the fuel consumption. So, the efficiency of vehicle also gets affected.

C. Methodology

- Visit to the industry
- Identification of problem
- Idea of project
- Collection of data
- Literature survey
- Design of CAD model
- Material selection
- Fabrication work
- Testing's
- Conclusion
- Submission of project

III. LITERATURE REVIEW

Matthieu Cosnier et al [1] presented an experimental and numerical study of a thermoelectric air-cooling and air-heating system. They have reached a cooling power of 50W per module, with a COP between 1.5 and 2, by supplying an electrical intensity of 4A and maintaining the 5°C temperature difference between the hot and cold sides.

Suwit Jugsujinda et al [2] conducted a study on analyzing thermoelectric refrigerator performance. The refrigeration system of thermoelectric refrigerator (TER; 25 × 25 × 35 cm3) was fabricated by using a thermoelectric cooler (TEC; 4 × 4 cm2) and applied electrical power of 40 W. The TER was decreased from 30 ºC to 20 ºC for 1 hr and slowly decreasing temperature for 24 hrs. The maximum COP of TEC and TER were 3.0 and 0.65.

Wei He et al [3] Conducted did Numerical study of Theoretical and experimental investigation of a thermoelectric cooling and heating system driven by solar. In summer, the thermoelectric device works as a Peltier cooler when electrical power supplied by PV/T modules is applied on it. The minimum temperature 17 degree C is achieved, with COP of the Thermoelectric device higher than 0.45. Then comparing simulation result and experimental data.

Riff and Guoquan [4] Conducted an experimental study of comparative investigation of thermoelectric air conditioners versus vapour compression and absorption air conditioners. Three types of domestic air conditioners are compared and compact air conditioner was fabricated.

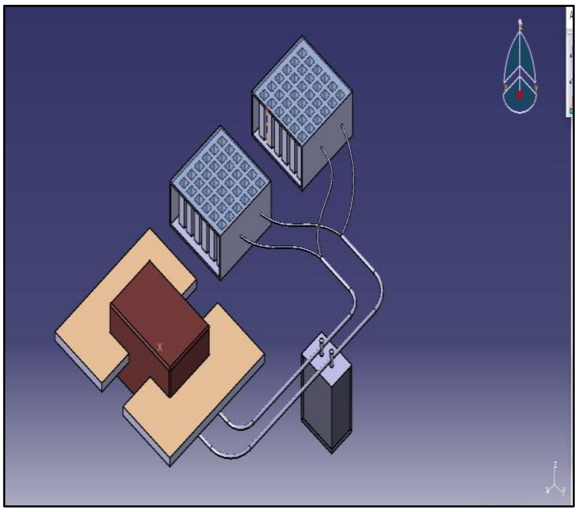
Riffat and Qiu [5] compared performances of thermoelectric and conventional vapor compression air-conditioners. Results show that the actual COPs of vapor compression and thermoelectric air-conditioners are in the range of 2.6-3.0 and 0.38-0.45, respectively. However, thermoelectric air conditioners have several advantageous features compared to their vapor-compression counterparts.

Astrain, Vian & Domınguez [6] conducted an experimental investigation of the COP in the thermoelectric refrigeration by the optimization of heat dissipation. In thermoelectric refrigeration based on the principle of a thermos syphon with phase change is presented. In the experimental optimization phase, a prototype of thermos syphon with a Thermal resistance of 0.110 K/W has been developed, dissipating the heat of a Peltier pellet with the size of 40*40*3.9 cm, experimentally proved that the use of thermos syphon with phase change increases the coefficient of performance up to 32%.

Shen, Xiao ET al [7] investigated a novel thermoelectric radiant air-conditioning system (TE-RAC). The system employs thermoelectric modules as radiant panels for indoor cooling, as well as for space heating by easily reversing the input current. Based on the analysis of a commercial thermoelectric module they have obtained a maximum cooling COP of 1.77 when applying an electric current of 1.2 A and maintaining cold side temperature at 20°C.

Virjoghe, Diana et al [8] conducted a numerical investigation of thermoelectric System. The thermoelectric systems have attracted renewed interest as concerns with the efficient use of energy resources, and the minimization of environmental damage, have become important current issues. This paper presents of numerical simulation for several the thermoelectric materials. Numerical simulation is carried out by using a finite element package ANSYS.

Maneewan et al [9] conducted an experimental investigation of thermal comfort study of compact thermoelectric air conditioner. In this paper analyse the cooling performance of compact thermoelectric air-conditioner. TEC1-12708 type thermoelectric modules used for heating and cooling application. The compact TE air conditioners COP was calculated to its optimum parameters. Then analyse the cop with respect to time and calculated cop at various considerations.



IV. COMPONENT OF THERMOELECTRIC AIR CONDITIONING

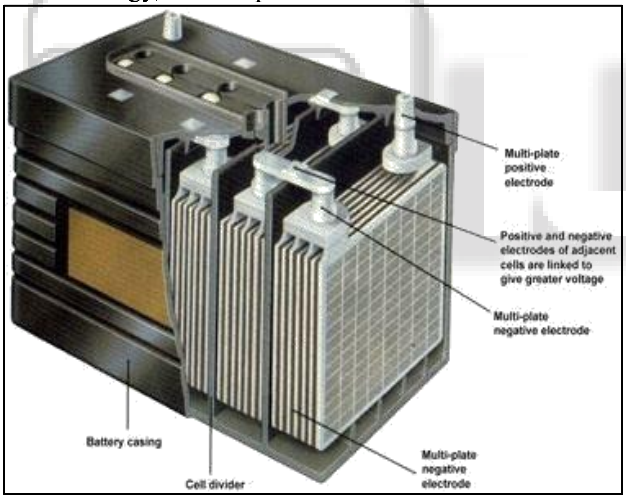
A. Thermoelectric Generater:

A thermoelectric generator (TEG), also called a Seebeck generator, is a solid state device that converts heat flux (temperature differences) directly into electrical energy through a phenomenon called the Seebeck Effect (a form of thermoelectric effect). Thermoelectric generators function like heat engines, but are less bulky and have no moving parts. However, TEGs are typically more expensive and less efficient

Thermoelectric generators could be used in power plants in order to convert waste heat into additional electrical power and in automobiles as automotive thermoelectric generators (ATGs) to increase fuel efficiency. Another application is radioisotope thermoelectric generators which are used in space probes, which has the same mechanism but use radioisotopes to generate the required heat difference.

1) Battery:

- In an internal combustion engine -powered vehicle, the battery is used mainly to start the engine. It is quite small but still pretty heavy, say 15kg- using lead-acid chemistry and will have a capacity of 40–100Amp-hours (Ah). Lead-acid is a very well established technology, it's inexpensive and reliable.



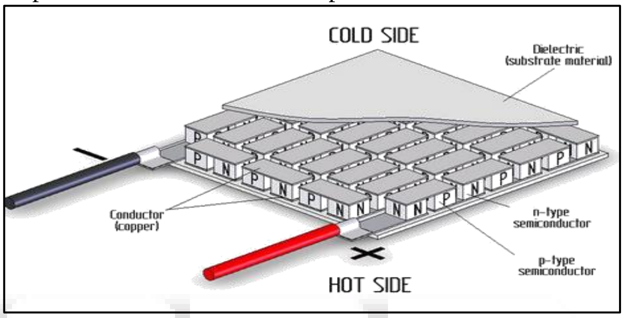
- A car's electrical power system is rated at 12 volts. When cranking the engine it will supply the starter motor with about 60–100Amps - which is a massive current requiring very thick cable - but only for a couple of seconds.
- It can also power the lights and radio when the engine is switched off - when the engine is running all the electrical accessories are supplied from the alternator. The alternator also charges the battery so it is ready for use the next time you want to start the car.

2) Peltier Plate:

Thermoelectric cooling has quickly become a practical proposition for many types of electronic equipment. Devices on the market today are compact, efficient and – with the benefit of advanced internal construction – overcome the traditional reliability challenges that have restricted opportunities for this type of device in the past.

Keeping electronic components like laser diodes or image sensors at a stable temperature is vital to ensure instruments such as high-power lasers, laboratory references, spectroscopes or night-vision systems can function correctly. In some cases, cooling to below ambient temperature may be required. Simple passive cooling, using a combination of a heat sink and forced-air, can struggle to satisfy either of these demands; response to changes in thermal load can be slow and imprecise, and cooling relies on a thermal gradient where the heat source temperature is higher than ambient.

As alternative to commonly used passive cooling techniques, thermoelectric cooling can offer numerous advantages. These include accurate temperature control and faster response, the opportunity for fanless operation (subject to heat sink performance), reduced noise, space savings, reduced power consumption and the ability to cool components to sub-ambient temperatures.



B. 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 resistor at the bottom is replaced with a voltmeter the circuit then functions as a temperature-sensing thermocouple. A thermoelectric circuit composed of materials of different Seebeck coefficient (p-doped and n-doped semiconductors), configured as a thermoelectric generator. If the load resistor at the bottom is replaced with a voltmeter the circuit then 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. Seebeck, 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 to the temperature difference in different ways, 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".

The Seebeck effect is a classic example of an electromotive force (emf) and leads to measurable currents or voltages in the same way as any other emf. Electromotive forces modify Ohm's law by generating currents even in the absence of voltage differences (or vice versa); the local current density is given by,

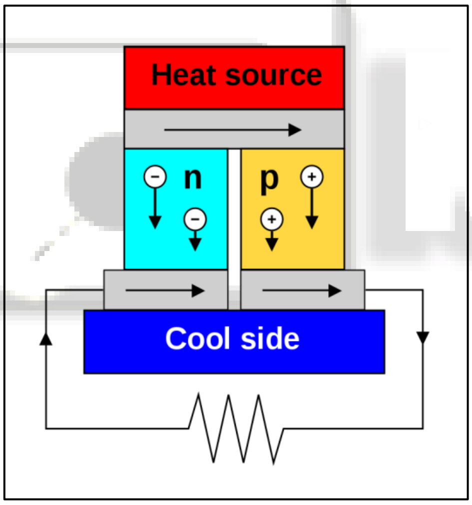
$$J=\sigma(-\Delta V + Eemf)$$

Where is the local voltage and is the local conductivity. In general, the Seebeck effect is described locally by the creation of an electromotive field

$$E_{emf} = -S\Delta T$$

Where S is the Seebeck coefficient (also known as thermo power), a property of the local material, and ΔT is the gradient in temperature T.

The Seebeck coefficients generally vary as function of temperature, and depend strongly on the composition of the conductor. For ordinary materials at room temperature, the Seebeck coefficient may range in value from −100 μV/K to +1,000 μV/K (see Seebeck coefficient article for more information).If the system reaches a steady state where J=0, then the voltage gradient is given simply by the emf -ΔV=SΔT. This simple relationship, which does not depend on conductivity, is used in the thermocouple to measure a temperature difference; an absolute temperature may be found by performing the voltage measurement at a known reference temperature. A metal of unknown composition can be classified by its thermoelectric effect if a metallic probe of known composition is kept at a constant temperature and held in contact with the unknown sample that is locally heated to the probe temperature. It is used commercially to identify metal alloys. Thermocouples in series form a thermopile. Thermoelectric generators are used for creating power from heat differentials

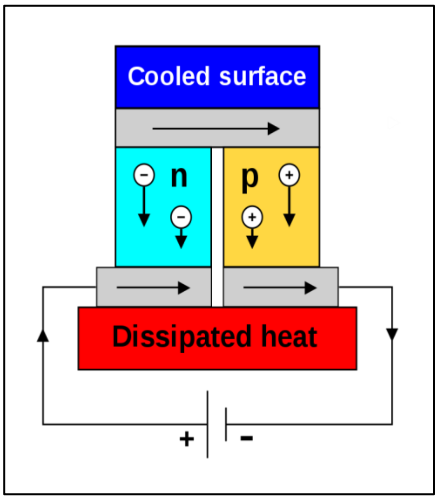


C. *Peltier effect (Reverse effect):*

The Peltier effect is the presence of heating or cooling at an electrified junction of two different conductors and is named after French physicist Jean Charles Athanase Peltier, who discovered it in 1834. When a current is made to flow through a junction between two conductors A and B, heat may be generated (or removed) at the junction. The Peltier heat generated at the junction per unit time, Q is equal to

$$Q= (\pi A- \pi B)I$$

Where πA, πB is the Peltier coefficient of conductor A and B, and I is the electric current (from A to B). Note that the total heat generated at the junction is not determined by the Peltier effect alone, as it may also be influenced by Joule heating and thermal gradient effects.



The Peltier coefficients represent how much heat is carried per unit charge. Since charge current must be continuous across a junction, the associated heat flow will develop a discontinuity if πA and πB are different. The Peltier effect can be considered as the back-action counterpart to the Seebeck effect (analogous to the back-emf in magnetic induction): if a simple thermoelectric circuit is closed then the Seebeck effect will drive a current, which in turn (via the Peltier effect) will always transfer heat from the hot to the cold junction. The close relationship between Peltier and Seebeck effects can be seen in the direct connection between their coefficients: π=T*S.

A typical Peltier heat pump device involves multiple junctions in series, through which a current is driven. Some of the junctions lose heat due to the Peltier effect, while others gain heat. Thermoelectric heat pumps exploit this phenomenon, as do thermoelectric cooling devices found in refrigerators.

D. *Thermoelectric Cooler*

1) *Peltier Thermo-Electric Cooler Module - 12V 5A:-*

a) Specification:

- Max current: 6A @ 12V
- Suggested Voltage range: 12V to 15.5V
- Maximum temperature differential (Tmax @ Qc = 0): 66°C
- Maximum cooling power (Qcmax) @ 15.3V: 97W
- 127 Peltier elements
- DC Resistance: 2.5 ohms
- Silicone seal
- Dimensions: 40mm / 1.57" x 40mm / 1.57" x 3.5mm / 0.13"
- Wire Length: 339.72mm / 13.32"
- Weight: 20.68g

E. *Thermoelectric Generator*

1) *Feature:*

Colding side posts with the words Heating side is empty Red wire to positive, black wire to the negative, it generate electricity when the temperature difference happened.

2) *Specification:*

- Model: SP1848-27145
- Color: white
- Lead Length: about 30CM

– Size: 40MM x 40MM x 3. 4MM
– 20 degree temperature difference: open-circuit voltage 0. 97V, generated current: 225MA
– 40 degree temperature difference: open circuit voltage 1. 8V, generated current: 368MA
– 60 degree temperature difference: open circuit voltage 2. 4V, generated current: 469MA
– 80 degree temperature difference: the open circuit voltage 3. 6V, generated current: 558MA
– 100 degree temperature difference: open circuit voltage 4. 8V, generated current: 669MA

The above values are for reference only, the wiring in actual use, and the step-up board, there will be loss of current Package included: 1 x 40x40MM Thermoelectric Power Generator Peltier Module

V. Result and discussion

After the study of thermoelectric refrigeration system, we could demonstrate the cooling ability of the Peltier module and its use as an alternative to refrigerant based cooling systems. The study concludes that there are a no. of places where TEC can play a more promising role than the conventional ACs with the added advantage of not using the refrigerants and hence protecting the ozone layer. With its reliable cooling and precise temperature control, this solid-state cooling technology can replace conventional cooling in a multitude of applications. Also with the advancements in material technology, there shall be a drastic rise in the cooling performance.

This project was just an effort to demonstrate the need and means of replacing the conventional systems due to their adverse environmental effects and to highlight the future scope of the Thermoelectric Cooling Devices.

VI. Concluding Remarks and Scope for the Future Work

Now a day, an automobile is a necessity for everybody. For a far or near travelling people need car regard to the safety, environment and most important comfort. Due to these reasons, many vehicles are equipped with heating, ventilating and air conditioning system. In vehicle without HVAC system no one feel comfortable so, HVAC together with part of people life. This HVAC system is more efficient and reliable but it has some limitations. It has been seen during the previous two decades that the ozone (O3) layer is slowly destroyed because of the refrigerant like CFC and HFC used for the refrigeration and air conditioning. The refrigerant used is HFC's which are leaked into the atmosphere. When they reach to ozone (O3) layer they act on O3 –molecules and the layer of O3 is destroyed.

It includes demerits like; the compressor is driven by the crankshaft of the engine. So, it consumes about 5 to10% power of the engine. This consequently reduces mileage of the vehicle. An Air-conditioning system consumes as much as 8h.p. with a unit capacity of 3 tons or 9072 kcal/hr. approximately. So, due to these the pickup of vehicle decreases. The cost of present HVAC system is more; it may vary depending upon price and model of vehicle. Maintenance and repairing cost of this system is more. Each component of HVAC is very costly. This system occupies very large space in engine compartment and dashboard. In this system, if any component fails to perform well then, the whole system either will not function properly or will not function at all. Instead of this, today's electronically and computer controlled HVAC system has sensors. If somebody wants to start an AC system, but due to high power requirement of an engine, the AC system will not start and person will need to wait for the starting of the HVAC system.

As a mechanical engineer we are trying to overcome these demerits by replacing the existing HVAC system by newly emerging thermoelectric couple or cooler which works on Peltier and seebeck effect. 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 modules it generates a heat transfer and temperature difference across the ceramics 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. Testing and measurements are also performed using on car. 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 Readings taken during testing also testify to the fact that the TE cooling for car can lower the ambient temperature by 7degree Celsius.

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