

Study of Thermoelectric Air Conditioning for Automobiles

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ABSTRACT: Air conditioning systems is used in many automobile applications. The conventional process using refrigerant can cause serious problems to the environment. In this study we developed the air conditioning system based on thermoelectric properties. In this air conditioning, there is no use of compressor and pump for the refrigeration. Thermoelectric module is an electrical module, which produces a temperature difference while current flow. The emergence of the temperature difference is based on Peltier effect. The thermoelectric module is a heat pump and has the same function as a refrigerator. The heat flow can be turned by reversal of the direction of the current. Our aim is to introduce the new HVAC system using thermoelectric module which shall overcome all the disadvantages of existing HVAC system.

KEYWORDS: Thermoelectric module, Peltier Effect, Seebeck effect, HVAC, Thermoelectric generator.

I. INTRODUCTION

In thermoelectric materials, electrical energy can be directly converted into thermal energy and thermal energy into electrical energy. Direct conversion between electrical and thermal energy is possible because of two important thermoelectric effects: the Seebeck effect and the Peltier effect. The Seebeck effect refers to the existence of an electric potential across a thermoelectric material subject to a temperature gradient. The Peltier effect refers to the absorption of heat into one end of a thermoelectric material and the release of heat from the opposite end due to a current flow through the material. Thermoelectric cooling, commonly referred to as cooling technology using thermoelectric coolers (TECs), has advantages of high reliability, no mechanical moving parts, compact in size and light in weight, and no working fluid. In addition, it possesses advantage that it can be powered by direct current (DC) electric sources. When a voltage or DC current is applied to two dissimilar conductors, a circuit can be created that allows for continuous heat transport between the conductors's junctions this is the principle of thermoelectric air-condition. Air conditioning is a process of removing heat from a room or other applications. Many ways of producing a cooling effect by like vapour compression and vapour absorption air condition. These air conditioners are producing cooling effect by using refrigerants like Freon and ammonia etc. It gives maximum output but, one of the disadvantage is producing harmful gases to the atmosphere. The harmful gases are chlorofluoro carbon and some other gases are present. These types of air conditioners have wide range of applications. An air conditioner is a major home appliance, system, or mechanism designed to change the air temperature and humidity within an area. The cooling is typically done using a simple refrigeration cycle, but sometimes evaporation is used, commonly for comfort cooling in buildings and motor vehicles. Normally we are used in the vapour compression air-condition system, it has many moving parts and as well as produce harmful gases to the environment. By using thermoelectric modules air-conditioners we can overcome the existing air-conditioning system by modifying it to protect the environment. A conventional cooling system contains three fundamental parts - the evaporator, compressor and condenser. The evaporator or cold section is the part where the pressurized refrigerant is allowed to expand, boil and evaporate. During this change of state from liquid to gas, energy (heat) is absorbed. The compressor acts as the refrigerant pump and recompresses the gas to a liquid. The condenser expels the heat absorbed in the evaporator plus the heat produced during compression, into the environment or ambient. A thermoelectric has analogous parts. At the cold junction, energy (heat) is absorbed by electrons as they pass from a low energy level in the p-type semiconductor element, to a higher energy level in the n-type semiconductor element. The power supply provides the energy to move the electrons through the system. At the hot junction, energy is expelled to a heat sink as electrons move from a high energy level element (n-type) to a lower energy level element (p-type).

II.OBJECTIVES

- 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, CO₂ 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.
- 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 carefficiency.
- 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 cost effective system
- 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.
- To fabricate working model of HVAC using TEC. To test HVAC using TEC for its effectiveness, efficiency, environment friendliness, comfort and convenience

III.METHODOLOGY

Thermoelectric Module:

A standard module consist so f any number of thermo couples connected in series and sandwiched between two ceramic plates (See Figure 3) . By applying a current to the module one ceramic plate is heated while the other is cooled. The direction of the current determines which plate is cooled. The number and size of the thermocouples as well as the materials used in the manufacturing determine the cooling capacity. Cooling capacity varies from fractions of Watts up to many hundreds. Different types of TEC modules are single stage, two stage, three stage, four stage, centrehole modules etc.



Fig. 2 A typical single stage thermoelectric module

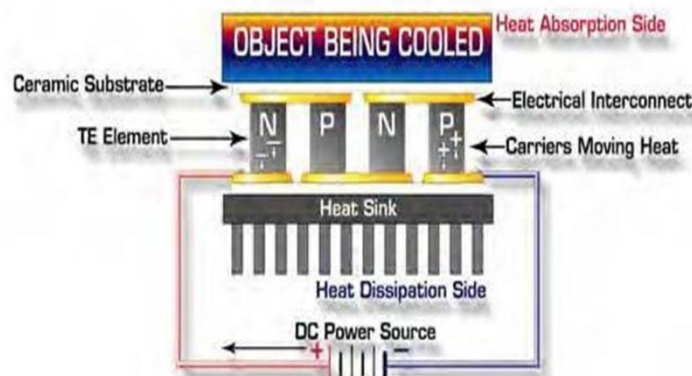


Fig. 3 A Classic TE Module Assembly

Before starting to design a TEC cooling system the designer have to take note the following into consideration.

1. Temperature to be maintained for the object that is to be cooled.
2. Heat to be removed from the cooled object.
3. Time required to attain the cooling after a DC power is applied.
4. Expected ambient temperature.
5. Space available for the module and hot side heatsink.
6. Expected temperature of hot side heatsink.
7. Power available for the TEC.
8. Controlling the temperature of the cooled object if necessary

Parameters of a Thermoelectric Module

Once it is decided that thermoelectric cooler is to be considered for cooling system, the next step is to select the thermoelectric module or cooler that can satisfy a particular set of requirements. Modules are available in great variety of sizes, shapes, operating currents, operating voltages and ranges of heat pumping capacity. The minimum specifications for finding an appropriate TEC by the designer must be based on the following parameters. The cutaway of a TEC is shown in Fig 4.

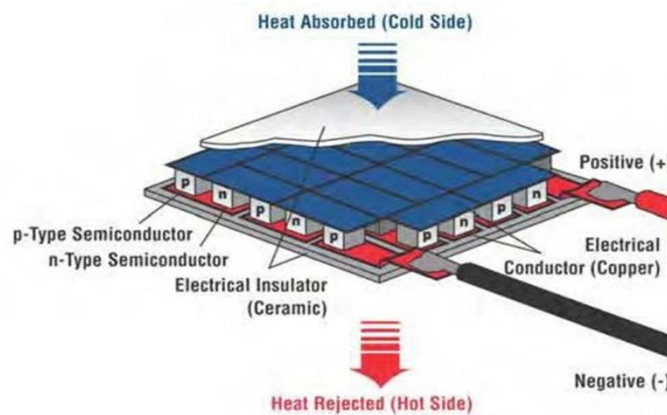


Fig. A Cutaway of Thermoelectric Module

- Cold side temperature (T_c)
- Hot side temperature (T_h)
- Operating temperature difference, which is the temperature difference between T_h and T_c .
- Amount of heat to be absorbed at the TEC's cold surface. This can also be termed as heat load. It is represented as (Q_c) and the unit is Watts.
- Operating current (I) and operating voltage (V) of the TEC.

Cold side temperature

If the object to be cooled is in direct contact with the cold surface of the TEC, the required temperature can be considered the temperature of the cold side of TEC (T_c). Here in this project the object is air inside the car, which has to be cooled when passed through a cluster of four Aluminium heat sinks. It is discussed in detail in the next chapter. The aim is to cool the air flowing through the heat sinks. When this type of system is employed the cold side temperature of the TEC is needed to be several time colder than the ultimate desired temperature of the air.

Hot side temperature

The hot side temperature (T_h) is mainly based on the two factors. First parameter is the temperature of the ambient air in environment to which the heat is been rejected. Second factor is the efficiency of the heat sink that is between the hot side of TEC and the ambient.

Temperature difference

The two temperatures T_c and T_h and the difference between them ΔT is a very important factor. ΔT has to be accurately determined if the cooling system is expected to be operating as desired. The following equation shows the actual ΔT .

$$\Delta T = T_h - T_c$$

Actual ΔT is not same as the system ΔT . Actual ΔT is the difference between the hot and cold side of the TEC. On the other hand system ΔT is the temperature difference between the ambient temperature and temperature of the load to be cooled.

Cooling Load

The most difficult and important factor to be accurately calculated for a TEC is the amount of heat to be removed or absorbed (Q_c) by the cold side of the TEC. In this project Q_c was calculated by finding the product of mass flow rate of air, specific heat of air and temperature difference. Here the temperature difference system ΔT in the difference between the inlet temperature and outlet temperature of the cooling system. The mathematical equation for Q_c is as shown below.

$$Q_c = m C_p \Delta T$$

Thermoelectric Assembly - Heat Sinks

Thermoelectric Assemblies (TEAs) are cooling or heating systems attached to the hot side of the TEC to transfer heat by air, liquid or conduction. TEAs which dissipate heat from the hot side use heat exchangers. TEC requires heat exchangers or heat sinks and will be damaged if operated without one. The two ΔT s, actual ΔT and system ΔT depend on the heat sinks fitted at the hot sides or cold sides of TEC. The thermal resistances of the heat sinks could vary the ΔT across the TEC for a set ambient temperature and cooling load temperature. Therefore the thermal resistance of the heat sinks could increase the current flowing through the TEC. The three basic types of heat sinks are: forced convective, natural convective and liquid cooled, where liquid cooled is the most effective. The typical allowances for ΔT at the hot side heat sink of a TEC are

1. 10 to 15 °C for a forced air cooling system with fins - Forced convection
2. 20 to 40 °C for cooling using free convection - Natural convection.
3. 2 to 5 °C for cooling using liquid heat exchangers - Liquid cooled.

There are several different types of heat exchangers available in the market. As far this project is concerned a forced convection type of heat sink was used based on the ΔT .

The main heat sink parameter for the selection process is its thermal resistance. Heat sink resistance can be termed as the measure of the capability of the sink to dissipate the applied heat. The equation is as follows.

$$R = (T_h - T_\infty) / Q_h$$

R is the thermal resistance (in °C /W or K/W) and T_h , the hot side temperature and T_∞ ambient temperature respectively. Q_h is the heat load into the heat sink which is the sum of TEC power P_e and heat absorbed.

$$Q_h = Q_c + P_e$$

The goal of a heat sink design is to lessen the thermal resistance. It can be attained through exposed surface area of the heat sink. It may also require forced air or liquid cooling.

IV. WORKING PRINCIPLE

The working principle based on

following; 1) Peltier effect

2) Seebeck effect

4.1 Peltier effect

It works on a principle that "When a Current (I) is made to flow through the circuit, heat is evolved at the lower junction (T_2) and absorbed at the upper junction (T_1). Peltier heat is reversible, when the direction of current is reversed; the Peltier heat is the same, but in opposite direction. Peltier coefficient depends on the temperature and materials of a junction.

Fig.1 Illustrates the Peltier Effect. Fig.1. Note that this effect will be reversed whereby a change in the direction of electric current flow will reverse the direction of heat flow.

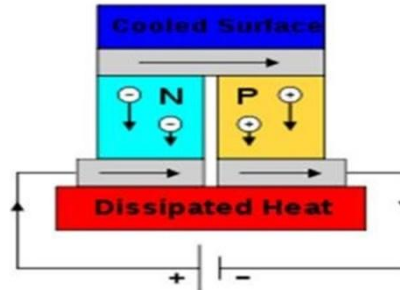


Fig.Peltier effect

Seebeck effect

Discovered by Thomas Johann Seebeck in 1821. He accidentally found that a voltage existed between two ends of a metal bar when a temperature gradient existed within the bar. The voltage is proportional to the temperature gradient. A temperature difference causes diffusion of electrons from the hot side to the cold side of a conductor. The motion of electrons creates an electric current. The voltage is proportional to the temperature difference as governed by:

$$V = \alpha(T_h - T_c)$$

where,

T_h = temperature of hot side of the module. T_c = temperatures of cold side of the module. α = coefficient of heat

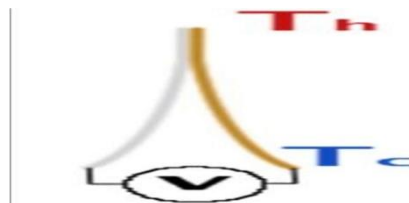


Fig.1.3.2 Seebeck effect

Thermoelectric Module Basic Configuration

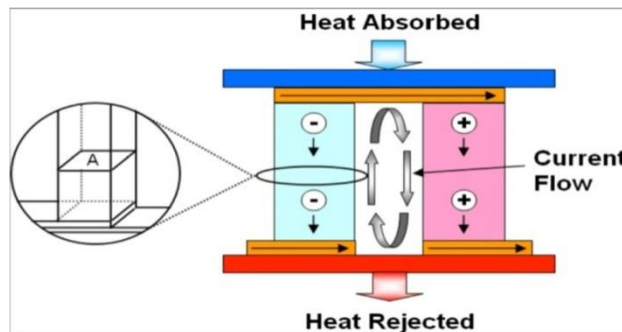


Fig. Thermoelectric couple basic configuration

The Peltier effect occurs when a voltage is applied to two connected electrical conductors made of different materials. When the voltage is applied, a circuit can be created that allows for continuous heat transport between the conductor's junctions the opposite also applies such that a voltage can be generated by applying a temperature difference to the two connected electrical conductors, which is known as the Seebeck effect.



This temperature difference results in a transfer of thermal energy across the electrical conductors and causes charge carriers to also diffuse through the materials. These charge carriers can be either electrons, or electron deficiencies called holes, and move with in the crystals of the materials by way of electron flow from the cold side to the hot side of the TE couple. The heat is transferred in the same direction as the charge carrier flow, from the cold side of the TE couple to the hot side. By leaving positively charged nuclei to collect on the cold side of the TE couple while the charge carriers move towards the hot side, a thermoelectric voltage is generated. This results in the potential to generate an electrical current if a complete circuit can be created.

V.RESULTS ANDDISCUSSIONS

Wagon R car has the following	
specification values [10] : MONTH :	JULY
TIME :	13:00 TO 16:00
LATITUDE :	21.7° N , 72.9°E
DRIVER HEIGHT :	1.7 m
DRIVER WEIGHT :	70 kg
PASSENGER HEIGHT :	1.6 m
PASSENGER WEIGHT :	55 kg
VENTILATION FLOW :	0.1 m3/sec
GROUND REFLECTIVITY :	0.02
AMBIENT TEMPERATURE :	35°C
INITIAL CABIN TEMPERATURE :	80°C
AMBIENT RELATIVE HUMIDITY :	70%
CABIN RELATIVE HUMIDITY :	50%
COMFORT TEMPERATURE :	23°C
PULL DOWN TIME :	10 min (600 sec)
DEEP THERMAL MASS :	5600 J/K

(1) Metabolic Load :

DuBois area AD_{uis} :

$$AD_u = 0.202W^{0.425}H^{0.725}$$

For Driver :

$$W = 70$$

$$\text{kg } H =$$

$$1.7 \text{ m}$$

$$AD_u = 0.202W^{0.425}H^{0.725}$$

$$= 0.202(70)^{0.425}(1.7)^{0.725}$$

$$= 1.80$$

$$m^2 \text{ } QM_1 = M$$

$$* AD_u$$

$$= 85 * 1.80 \text{ (for Driver , } M = 85 \text{ W/m}^2\text{)}$$

$$= 153 \text{ W}$$

For Passenger :

$$W = 55$$

$$\text{kg } H =$$

$$1.6 \text{ m}$$

$$AD_u = 0.202W^{0.425}H^{0.725}$$



$$= 0.202(55)0.425(1.7) 0.725$$

$$= 1.55 \text{ m}^2$$

$$QM2 = M * ADu$$

$$= 55 * 1.55 \text{ (for Passenger , M = 55 W/m}^2\text{)}$$

$$= 85.7 \text{ W}$$

$$QM = QM1 + QM2$$

$$= 153 + 85.7$$

$$= 238.7 \text{ W}$$

$$\approx 240 \text{ W}$$

2) Radiation Load

- (a) Direct Radiation load = 1000W
- (b) Diffuse Radiation load = 190W
- (c) Reflected radiation load = 0W
- (3) Ambient Load = - 200W
- (4) Exhaust Load = 0 W
- (5) Engine Load = 0W
- (6) Ventilation Load = - 1000W
- (7) AC Load = -2800W

$$\text{TOTAL LOAD} = 240 + 1000 + 190 + 0 - 200 + 0 + 0 - 1000 - 2800$$

$$= -2570 \text{ W (Since cooling is done in summer , this load is negative)}$$

As per our load we can select no. of peltier plates

$$= \frac{\text{Total load (i W)}}{\text{cooling capacity of one peltier plate (in W)}}$$

$$= \frac{2570}{2570}$$



$$= \frac{\quad}{97}$$

$$= 26$$

For Both Conductive and convective heat transfer component of load, we can use this equation

$$Q = \frac{\Delta T * A}{\frac{L}{h * K}}$$

Inside temp.of cabin- 8⁰ C

Outside Temp or Ambient temp

$$= 30^0 \text{ C Temp. Difference} = (30 - 8)$$

$$= 22^0 \text{ C}$$

Thermal conductivity of expandable polystyrene, Keps = 0.033

W/mk Heat transfer coefficient h_{air} = 10 w/m²k

$$\text{Area} = L * B$$

$$= 0.4 * 0.4$$

$$= 0.16$$

$$Q = \frac{22 * 0.16}{\frac{0.015}{10 * 0.033}} = 5.377$$

Infiltration air load due to opening and closing Q_c=10

$$\text{W TOTAL LOAD} = Q_p + Q_c$$

$$= 5.377 + 10$$

$$= 15.377$$

So for

safety

$$Q \approx 25 \text{ W}$$

So we design system with

$$Q = 25 \text{ W}$$

T_A = 30 maximum ambient air

temperature T_C = 8⁰ required

temperature of cabin

TEC Selection:

The TEC module was selected by considering few factors such as dimensions, Q_{TEC}. The model number of the module is Peltier Thermo-Electric Cooler Module - 12V 5A . It is decided to select a TEC module which has a cooling power greater than the calculated cooling load. Which is operates with an optimum voltage value of 12V. It has a maximum voltage of 15.3V. At 12V it draws and maximum DC current of 6 A.

Specification:

Max current: 6A @ 12V

Suggested Voltage range: 12V to 15.5V

Maximum temperature differential (T_{max} @ Q_c = 0):

66°C Maximum cooling power (Q_{cmax}) @ 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

VI.CONCLUSION

A Thermoelectric Air cooling & heating system was designed and built which can be used for personal cooling & heating. Four TECs were used for achieving the cooling with a DC power supply through external power supply (dimmer stat). It had been shown from testing results that the cooling system is capable of cooling & heating the air when recirculating the air with the help of blower. TEC cooling designed was able to cool an ambient air temperature from 32.5°C to 22.1°C. Cooling stabilizes within ten minutes once the blower is turned ON (with a



velocity of 2.5 m/s). The system can attain a temperature difference of set target which was 6°C. Accomplishing the set target establish the success of the project. All the components in the project had been tested individually and the results were found to be positive.

The prototype can be made compact by selecting as single TEC of higher power (i.e. of 200W or more). It can be done by choosing a better cold side heat sink that has twisted channels or pipes for circulating the air for a longer time. As an alternative for normal axial fan used in this project, if a blower fans is selected, the cooling system would provide better airflow. Even as shown in the appended figure we can mount no of TEC cooling in Well-known TEC brands (i.e. Melcor, Ferro TEC etc) must be chosen if there is only one high power TEC selected for the cooling system. Bigger hot side heat sink has to be selected accurately based on its calculated thermal resistances for best cooling efficiency. With a single TEC, one hot side and a cold side heat sink a smaller personal TEC cooler which gives comfort can be fabricated and can be installed on roof for individual cooling by changing the airflow and some mechanical or electronics section modification, the TEC aircooling for car can be used for heating applications too.

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