DESIGN AND EXPERIMENTAL ANALYSIS OF THERMO ELECTRIC AIR CONDITIONER FOR CAR AND POWER GENERATION SYSTEM WITH ULTRA COOLING

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Abstract - Since some decades of science invention we saw the various improvements. Thermoelectric phenomena, the idea emerges from the thermocouple which imparts concept of gaining potential difference by maintaining two junctions at different temperatures. The maintenance of temperature at two different junctions causes power generation, refrigeration and air conditioning respectively and vice versa. Find this is also a way to overcome the environmental pollution caused by conventional system due to the direct conversion of temperature difference into voltage gradient without any mechanical systems. The purpose of this paper is utilisation of thermo electric phenomena by applying pelttier effect in various sectors. In This paper we have also mention the application of thermoelectric phenomena which is playing a vital role room conditioning for industries, domestic areas and all sorts of areas along with the ultra-cooling system for maintaining the two junctions at different temperatures.

Index terms - Peltier effect, thermoelectric phenomena, thermocouple, thermoelectric, thermoelectric module, potential difference, voltage gradient, seebeck effect.

I. INTRODUCTION

The basic concept behind the thermoelectric phenomenon is converting thermal energy into electrical energy and vice versa. The thermoelectric device is termed as thermoelectric generator (TEG) when it is generating the energy, since the thermal energy known itself as a temperature difference across the TEG. When device is performing in a cooling or heating medium the thermoelectric device is named as a thermoelectric cooler(TEC).Thermoelectric devices are not having any moving parts, which are reducing the susceptibility to mechanical failure while allowed to work for prolong periods with minimum maintenance. Additionally, this allows good cooling performances compared to conventional refrigeration systems and produce no pollutants or by-products which are disturbing the environment. These advantages make thermoelectric devices to replace in multiple applications. Especially for power generation applications thermoelectric devices are applied in automobiles where the waste heat in the exhaust gas has to be recovered as waste heat recovery device [1].

The thermal energy in the waste heat is grabbed along the exhaust line of vehicle and converted into useful electricity. Thermoelectric materials are directly converting electrical energy into thermal energy and thermal energy into electrical energy, this is possible because of two thermoelectric effects. One is seebeck effect [2] and the other is Peltier effect which we are discussing right now. Rovers who are used in space exploration are converting heat energy releasing from the decay of radioisotopes electricity [3]. Thermo electric generators which are working under the solar section grabs the incoming sunlight and convert this solar thermal energy into electricity by utilising thermoelectric principles [4] thermoelectric devices are also Imparted for ventilation, heating and air conditioning in automobiles [5]. These thermoelectric air conditioners and climate controlled seats may replace conventional air conditioning systems in vehicles. Thermoelectric devices are capable candidates for handling the surgical tools and fibre-optic lasers because of their huge manufacturability. These devises are also be employed into the microprocessors in order to achieve precise temperature control. When there is limited space around the microprocessor [6].

II. WORKING PRINCIPLE

Generally when the two conductors are in electrically contact, electrons flow from one in which they are less bound, into the other one where electrons are more bound. This phenomenon is due to the fermi level difference in the two conductors. Fermi level denotes the difference in the energy levels occupied by electrons to that of unoccupied of a metal conduction band. When the two different Fermi level conductors make contact, electrons flow from higher level to the lower level until the change in electrostatic potential brings the two Fermi levels to the same level. Current passes through the junction resulting a temperature gradient in any one of forward or reverse bias. If we maintain the heat sink at low temperature by removing the generated heat, the temperature at the cold plate side can be cooled by tens of degrees.

Aspects of Thermoelectric module
Some of the attractive specifications of thermoelectric modules are:
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1. Thermoelectric modules works without any moving parts i.e. they works electrically so less maintenance.

2. Thermoelectric cooling systems are smaller in structure and lighter in weight than the mechanical systems. Wide standards and special sizes and configurations are present in market to meet the requirements.

3. Conventional heat sinks where the temperature is necessarily must above the ambient, if we attach thermoelectric device to the same heat sink to reduce the temperature beyond ambient value.

4. Temperature control should be precise due to the closed-loop temperature control circuit.

5. Due to their solid state construction they are highly reliable. This reliability factor is application dependent.

6. Unlike a mechanical refrigeration system, thermoelectric modules generate no electrical noise. They can be used along with sensitive electronic sensors. They are silent and efficient.

7. Thermoelectric modules are working in zero gravity environment so they are popular in many aerospace applications.

8. Thermoelectric devices are operating directly from DC power source.

9. With the thermoelectric devices we can able to achieve spot cooling In fraction of time to the conventional systems in automobiles.

10. When the utilisation is reverse in order that is by applying temperature difference across it is responsible to generate DC power.

11. Conventional refrigeration systems are utilising chemical and CFCs which are harmful to environment. But thermoelectric devices does not use of any kind.

12. One more benefit of thermoelectric device is due to the direct conversion of thermal energy to electrical energy, direct conversion eliminates the losses associated. Conversion done in solid state of the device as such there is no moving parts and no wear.

III. DESIGN OF SETUP

In the current practical work we are using the medium car shaped structure with the proper dimensions. The dimensions of 5 feet length and 3 feet width. The height of the setup is 4.5 feet, setup is designed in 2D and 3D. For 2D designing we are using the Autocad as for 3D design Catia is the software used. Not only the design, we did the thermal analysis of the system by using the solid works. The given shown design diagrams are showing the different views of setup:

Figure 1 3d design of the experimental setup

IV. THERMAL ANALYSIS

Here analysis is done for two different conditions. One is when the car is in movement and the other is in rest condition of car. Analysis for setup while it is in the moving condition is done with forced convection, where as for other condition analysis is done without forced convection. But done by only considering the temperature of outer section of car body. Analysis is done by the solidwork software.

Figure 2 Analysis for Car in Rest Position without Forced Convection (outer and section view)

While doing the analysis for car in rest condition, applied values like outer body temperature is 34°C and interior body temperature is 24°C. Convective coefficient of atmospheric air of low posed is 10 W/m²k. But for the car is in moving condition outer body temperature is 34°C and interior temperature of
the setup is 24°C. Convective coefficient of atmospheric air of posed condition is 100 w/m²K for outside and for inside of the body it is 10w/m²K.

Once again mentioning the conditions of analysis, forced convection for car is in moving condition and when car is in rest without forced convection. Variation of temperatures had shown in different colours out of which red colour represent the outer body temperature and blue colour for interior temperature of the setup when car is in rest position. While car is in moving condition green colour shows the outer body temperature and blue colour represents the interior temperature of whole setup. Temperature variation shown in the analysis mentioned in K.

VI. ULTRA COOLING SYSTEM

In this project we are introducing a new concept named as ultra-cooling system. Here we are using a centrifugal pump for circulating the specialised liquid which is used for transferring the heat energy for maintaining the temperature at 70 degree between the two surfaces of thermoelectric system. we have made a thin rectangular box of galvanised sheet metal which is having two ports one is inlet and other one is outlet. Here we are going to circulate the coolant with the help of centrifugal pump from the reservoir to the rectangular box where the thermo electric is situated. Therefore our system is completely made for maintaining the temperature in a minimum level for producing the emf on the basis of principle called seebeck effect.

Hence the working is nothing but the coolant liquid is pumped by the centrifugal pump (12 v dc.) from the reservoir and discharged into the pipeline. This flow line (pipeline) transfers the liquid into the rectangular box where semi conductors are placed. The coolant which we are using will absorb the entire heat energy from the wall of the semiconductors and move into the radiator for dissipating the temperature from its molecules. Hence the coolant will again gathered in a reservoir and starts its cyclic process with the help of centrifugal pump.

VII. HEAT EXCHANGER

This is the circuit which is going to transfer the heat energy from the exhaust manifold of the ic engine. The heat energy is absorb by the liquid which we are using and therefore carry the heat energy to the upper thin box through pipe line with the help of the centrifugal pump, there the thermoelectric materials are facing the hot side of the box for absorbing the heat energy. From the outlet it will return back to the reservoir again. By doing this we can achieve the 70degree temperature difference for creating the emf.

While the vehicle is not moving i.e. in the parking condition we can grasp the heat energy from the sunlight by the external heat energy grasping
system. Which is nothing but we are placing the lenses on the top of the upper thin box, already coated with the black colour.

Figure 6 Helical structure copper rods

Figure 7 Upper Thin Box Coated With Black Colour

Figure 8 Thin Boxes

A simple logic of black body radiation, for this we have to calculate the focal length for the lenses. After calculating the focal length of the lenses we have to arrange the lenses accordingly. This is the other source of utilising the heat energy from the sun light when the vehicle is in the rest condition.

VIII. SOLAR ENERGY SOURCE

Here in this project we are using the 12V each solar panel, totally we are using five solar panels. by connecting them in the series we are producing the 60V. this produced power we can use as the other source of heat energy for the production of the emf.

We are not going to connect the thermoelectric setup to the produced power directly. In between we are using the electrical circuit for charging the battery (7amps) constantly. Through this we are supplying the produce electrical energy to the thermo electric setup.

These are all the ways of utilising heat energy for the production of the emf as well as the chillness inside the compartment. Here in this project we are utilising the two different kinds of switches for shifting the circuits of different operations. One switch we are using for producing the chillness and the other one is for the producing the emf. if we switch on the air conditioner switch the power from the circuit will be given to the thermo electrical setup, which is getting heat and produce the chillness at the other side i.e inside of the cabin. For dispersing the chillness throughout the cabin we are using the blower which will run in the opposite direction to its actual nature. The material we are using for the thermo electric setup is made-up of the material bismuth-telluride and the capacity will be of 90 watt max. then switch off this and switch on the other circuit. Then coming into the discussion about the emf producing circuit, heat energy from the engine manifold is connected to the reservoir where it is filling with the hot water. We made piece which is having the helical structure, should be kept inside the reservoir for dispersing the heat to the water in the reservoir. With help of centrifugal pump this hot water from the reservoir will circulate into the thin box which was placed at the top. through the outlet water again coming back to the reservoir. at the other end in the same way like hot water coolant from the other reservoir will be circulated through the bottom thin box and the outlet should connected to the radiator where the absorbing...
heat should be removed. So with the help of these two liquid flowing circuits there should be a temperature difference, so for producing the emf we need at least 70 degree celsius, by this we can able to generate the emf.

IX. RESULTS AND DISCUSSION

Here we are going to discuss about the results what we are recording during the time of testing. While performing the testing for the fabricated part we considered the ambient temperature of the system is 38°C. For performing the testing, we are using the two liquids in this project one is water and the other one is act as a coolant which is servo cool plus. And coming into the concept of the procedure of testing, we have used temperature sensor, multimeter and the stop watch. While calculating the amount of amps by using the multimeter we need to apply some load against the system. So our load has to be a 7amps battery, here we charging the 7amps battery which is connected with the thermoelectric system for supplying electrical power. during the testing For every 5 minutes readings has been noted down using the different equipment’s, we have mentioned already. The discussion is done through the plotted graphs by using the noted values during the testing.

For calculating the amount of emf induced in the system, we need to concentrate mainly on the temperature difference between the hot and cold junctions. There should be a difference of minimum of 70°C. Maximum of 12V we can produce through the system, as you can see the voltage production is increasing with the junction temperature is increasing. This graph shown us the amount of emf induced in the system is 11.8V. With this induced emf we can run the equipment’s like pumps for transferring the different liquids which we are using in the experimental setup.

The amount of chillness produced inside the cabin should be done by consuming voltage which is supplying to the system. By considering the ambient temperature of the system which is at 38°C, the temperature inside the cabin is keep on decreasing to the 0°C by consuming the maximum voltage which is 11.8V. But just on the surface of the cold junction only we can get the 0°C. 16°C to 18°C Temperature can be achieved by the consumption of 7.2V to 8.4V.
Here it is clear that the temperature difference between the hot and cold junction is 90°C. When the cold junction temperature is decreasing from the 40°C to the 0°C and the hot junction temperature is increasing from 0°C to 90°C, difference of temperature between the hot and cold junction will be the start for the emf.

![Air Conditioning Graph](image)

**Figure 15 Comparisons between Time and Temperature (Air Conditioning Graph)**

With this graph we can understand that the amount of time required for the cabin to get cool. Starting from the recording reading for every five minutes, it will take 15 to 20 minutes to reach the 18°C and 16°C. For the emf we need to maintain the surface of the cold junction at 0°C, for reaching the minimum temperature we need 30 minutes

![EMF Graph](image)

**Figure 16 Comparisons between Voltage and Temperature (EMF Graph)**

Amount of voltage produced per every five minutes is recorded as a graph here. Starting from the first 5 minutes the recorded voltage start from the 2.4volts to the 10.2volts at the end of 25 minutes, so, finally for achieving the 12V we need to operate the system for the 30 to 35 minutes. After achieving the 12V the voltage will show the constant in the graph because we can get maximum of 12V with this system

![Voltage V over Time](image)

**As a Power Generator**
A thermoelectric module is a solid state device which converts thermal energy to electrical energy directly due to the presence of temperature gradient. This process based on the seebeck effect in which electrons (charge carriers) serves as a working fluid. There is no effective conversion efficiency; almost less than 5% is the biggest drawback. This has been the reason for restricting the thermoelectric devices in the power generation fields. Sectors like industries, defence, medicine and aerospace are utilising for spot power generation.

**Power Generation Using Solar Energy**
Now a day the demand for the energy is raising on the earth. So the searching started for the new sources of energy. In unconventional sources solar energy is the inexhaustible and clean source. Here the combination of solar thermal collector and thermoelectric generator will produce the electrical energy. In 1821 thomson seebeck discovered the seebeck effect. When the temperature difference is formed between two different semiconductors or metals a voltage is generated and people named it as a seebeck voltage.

![Voltage V over Time](image)

**As a Air conditioner or Refrigerator**
It is a solid state refrigeration and it has the durability also. Not employing any fluids, long pipes and moving parts except some fans where they are necessary is the big advantage by comparing with conventional vapour cycle cooling systems. These advantages will help to consider thermoelectric cooling systems where conventional systems would fail. Thermoelectric cooling will produce much narrow temperatures where the conventional refrigeration cannot. If we require much more ΔT, can be achieved by cascading the modules on top of other.

**Condensation of Water with the Combination of Solar Thermoelectric Devices**
This system is having the heat exchangers, solar panels and thermoelectric cooling setup. We can produce water from the surrounding humid air and can be very useful in the deserts. We can produce 1L of water in the high humidity see area. This is economically not secured one but if we installed once requires much less maintenance cost. Development of such equipment’s would be the future business possibility.

**Utilisation in Medical Sciences**
At present this thermoelectric cooling is used in many fields of science and technology, especially in medicine. In serving the human this temperature effects are playing major role for many diseases. Generally in hospitals for achieving low temperatures liquid nitrogen is used in the systems. But most of the times systems become bulky for the application, then replaced by the thermoelectric coolers. Use of thermal effects on the patient arises some limits can be solved by using thermoelectric systems. In particular thermoelectric devices are implementing in the skin treatment like plastic surgery, dermatology, etc. so
therefore, improving and developing the thermoelectric medicine devices are important.

CONCLUSION

This paper is describing the design and experimental analysis of thermoelectric air conditioner and power generation system with ultra cooling along with the applications of the thermoelectric cooling in the different sectors, which are

1. Thermoelectric devices are using practically in many areas like defence, aerospace, medical sciences and commercial products which are named as coolers generators and sensors depends on the application.
2. Due to the weak coupling between electrical and heat currents of many materials thermoelectrical technology is not widely popular. And one more disadvantage of weak coupling is low efficiency. So the invention of more P and N-type semiconductors will be the good solution for this drawback.

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REFERENCES