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A

Project Report

On

(An Experimental investigation of Thermoelectric Air Cooling Module in Automobiles)

Prepared as a part of the requirements for the subject of

PROJECT – II

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(MECHANICAL BRANCH)

Submitted by:

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INDEX

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CERTIFICATE

This is to certify that the dissertation entitled "An Experimental investigation of Thermoelectric Air Cooling Module in Automobiles" has been carried out by *(Pragnesh Prajapati, Ajay Arya, Karan Dabhi, Vikas Prajapati)* under my guidance in fulfillment of the experiment of subject *PROJECT-2* in Mechanical Engineering (8thSemester) of Gujarat Technological University, Ahmedabad during academic year 2016-17.

Guided By **H.O.D**

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ABSTRACT

As the population increase the no. of vehicles also increase. Today, an automobile is a necessity for everyone. For a long or short journey people need car regard to the safety, environment and most important comfort. Owing to these reasons, many vehicles are equipped with heating, ventilating and air conditioning system. In today's world, no one feel comfortable in a vehicle without HVAC system. Therefore, HVAC becomes an integral part of human life. 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 O_3 –layer is slowly destroyed because of the refrigerant (CFC and HFC) used for the refrigeration and air – conditioning purposes. Other demerits includes: - 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.

This project is trying to overcome these demerits by replacing the existing HVAC system by newly emerging thermoelectric couple or cooler which works on peltier 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 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.

LIST OF FIGURES

LIST OF TABLES

CHAPTER-1

INTRODUCTION

1.1 What is the current scenario?

India is the second most populous country in the world with over 1.21billion people (estimated for April, 2011), more than sixth of the world's population. India is projected to be world's most populous country by 2025,surpassing china, its population exceeding 1.6 billion people by 2050.Comparing with the population there are 2.65 million cars sold in India as of march 2011.According to the society of Indian automotive manufacturer, annual car sales are projected to increase up to 5 million vehicles by 2015 and more than a 9 million by 2020.By 2050,the country is expected to top of the world in car volumes with approximately 611 million vehicles on the nation's roads.

The above data shows that, as the population increase the no. of vehicles also increase. Today, an automobile is a necessity for everyone. For a long or short journey people need car regard to the safety, environment and most important comfort. Owing to these reasons, many vehicles are equipped with heating, ventilating and air conditioning system. In today's world, no one feel comfortable in a vehicle without HVAC system. Therefore, HVAC becomes an integral part of human life. 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 thousands 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. Even the percentage of HFC's are emitted into the atmosphere compared to CO2 is negligible but its global warming effect is few thousand times of CO2.The effect of 100gm of HFC's can destroy 0.5 tons of O3 molecule. These HFC's once destroy O3-layer; it takes lack of years to recover its thickness as it is formed by complex reactions. This is because as HFC's comes in environment they remain in atmosphere for 18 years. The capacity of HFC's to increase in earth temperature 10% is contributed by HFC's only.

Other demerits includes: - 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 very high; it may vary depending upon price and model of vehicle.

Maintenance and repairing cost of this system is very high. 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 a 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.

1.2 What efforts are done in this project?

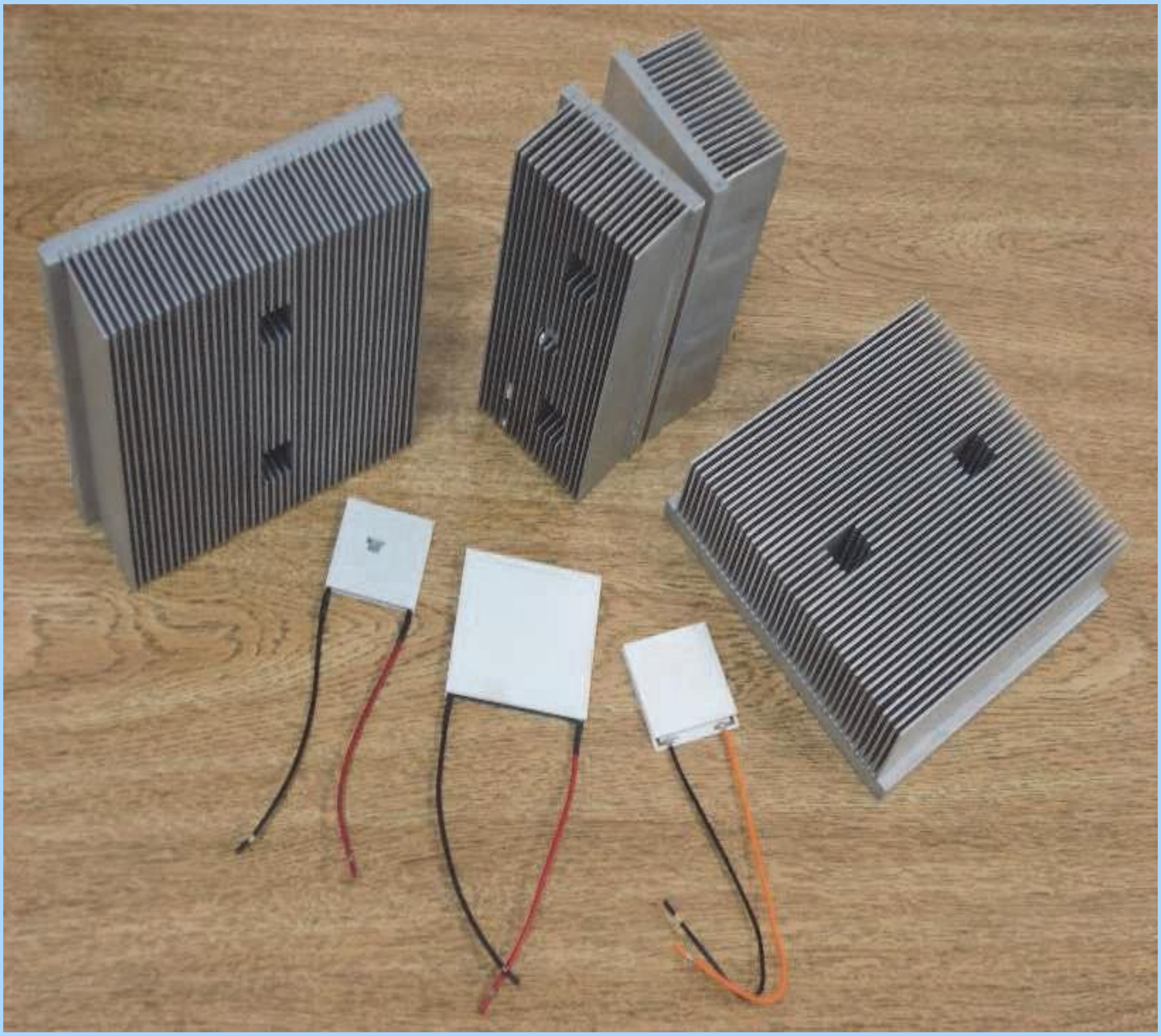
This project is trying to overcome these demerits by replacing the existing HVAC system by newly emerging thermoelectric couple or cooler which works on peltier and seebeck effect. Thermoelectric cooling can be considered as one of the major applications of thermoelectric modules (TEM) or thermoelectric 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 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. 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 7 degree Celsius.

1.3 What is Seebeck Effect?

Thermoelectric conversion was discovered towards the end of the 19th century. Electrons are capable of carrying heat, as well as electricity. When a temperature difference exists between the two end faces of a thermoelectric material, many electrons will travel from the hot end face to the cold one. This phenomenon is known as the Seebeck effect and forms the basis on which the thermoelectric generation module was developed. As we are all aware, the global energy crisis is becoming worse and much emphasis is being placed on environment protection and the recovery of energy resources. These include waste heat from cooling water, exhaust gas, and steam power plants, amongst others. TEG modules are light and silent, have no moving parts and can convert recycled heat directly into electricity.

CHAPTER-2

THERMOELECTRIC CONVERSION



2.1 Historical Background

Although commercial thermoelectric modules were not available until almost 1960, the physical principles upon which modern thermoelectric coolers are based actually date back to the early 1800s.

The first important discovery relating to thermoelectricity occurred in 1821 when German scientist Thomas Seebeck found that an electric current would flow continuously in a closed circuit made up of two dissimilar metals, provided that the junctions of the metals were maintained at two different temperatures. Seebeck did not actually comprehend the scientific basis for his discovery, however, and falsely assumed that flowing heat produced the same effect as flowing electric current.

In 1834, a French watchmaker and part-time physicist, Jean Peltier, while investigating the Seebeck Effect, found that there was an opposite phenomenon where by 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 relationship. At the time, however, these phenomena were still considered to be mere laboratory curiosities and were without practical application.

In the 1930s, Russian scientists began studying some of the earlier thermoelectric work in an effort to construct power generators for use at remote locations throughout their 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 in which doped semiconductor material takes the place of the 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.

2.2 Introduction

Thermoelectric are based on the Peltier Effect, The Peltier Effect is one of the three thermoelectric effects; the other two are known as the Seebeck Effect and Thomson Effect. Whereas the last two effects act on a single conductor, the Peltier Effect is a typical junction phenomenon.

Thermoelectric coolers are solid state heat pumps used in applications where temperature stabilization, temperature cycling, or cooling below ambient are required. There are many products using thermoelectric coolers, including CCD cameras (charge coupled device), laser diodes, microprocessors, blood analyzers and portable picnic coolers. This article discusses the theory behind the thermoelectric cooler, along with the thermal and electrical parameters involved.

2.3 Seebeck Effect

Seebeck Effect The conductors are two dissimilar metals denoted as material A and material B. The junction temperature at A is used as a reference and is maintained at a relatively cool temperature (T_C). The junction temperature at B is used as temperature higher than temperature T_C. With heat applied to junction B, a voltage (Eout) will appear across terminals T_1 and T_2 and hence an electric current would flow continuously in this closed circuit. This voltage as shown in Figure 2.1, known as the Seebeck EMF, can be expressed as

$$E_{out} = \alpha \, (T_H - T_C) \qquad (2.1)$$

Where: $\alpha = dE / dT = \alpha_A - \alpha_B$

- α is the differential Seebeck coefficient or (thermo electric power coefficient) between the two materials, A and B, positive when the direction of electric current is same as the direction of thermal current, in volts per ^oK.
- E_{out} is the output voltage in volts.
- TH and T_C are the hot and cold thermocouple temperatures, respectively, in ^oK.

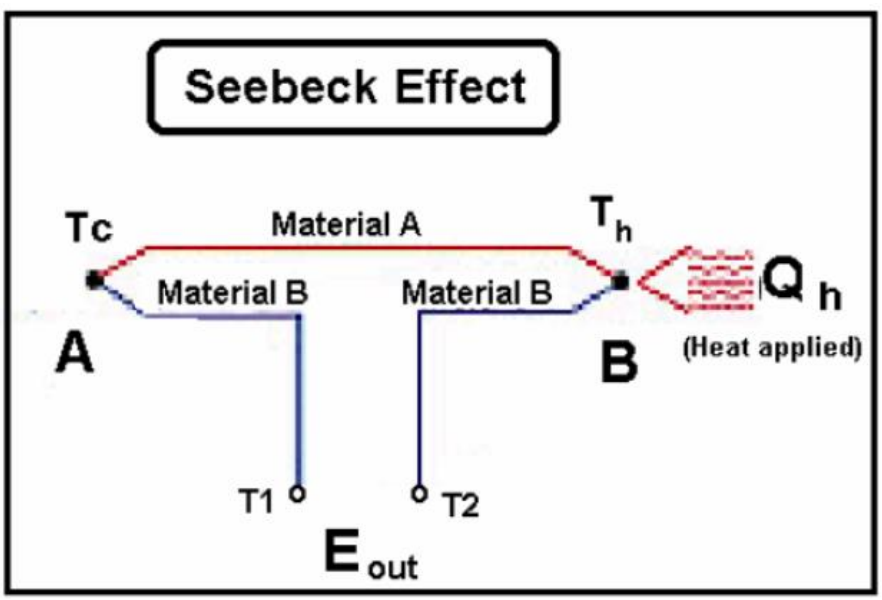


Figure 2.1 Principle of Seebeck effect

2.4 Peltier Effect

Peltier found there was an opposite phenomenon to the Seebeck Effect, 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. In Figure 2.2, the thermocouple circuit is modified to obtain a different configuration that illustrates the Peltier Effect, a phenomenon opposite that of the Seebeck Effect. If a voltage (E_{in}) is applied to terminals T1 and T2, an electrical current (I) will flow in the circuit. As a result of the current flow, a slight cooling effect (QC) will occur at thermocouple junction A (where heat is absorbed), and a heating effect (QH) will occur at junction B (where heat is expelled). Note that this effect may be reversed whereby a change in the direction of electric current flow will reverse the direction of heat flow. Joule heating, having a magnitude of I2 x R (where R is the electrical resistance), also occurs in the conductors as a result of current flow. This Joule heating effect acts in opposition to the Peltier Effect and causes a net reduction of the available cooling. The Peltier effect can be expressed mathematically as

$$Q_C \text{ or } Q_H = \beta \times I \qquad (2.2)$$
$$= (\alpha T) \times I$$

Where:

- β is the differential Peltier coefficient between the two materials A and B in volts.
- I is the electric current flow in amperes.
- Q_C and Q_H are the rates of cooling and heating, respectively, in watts

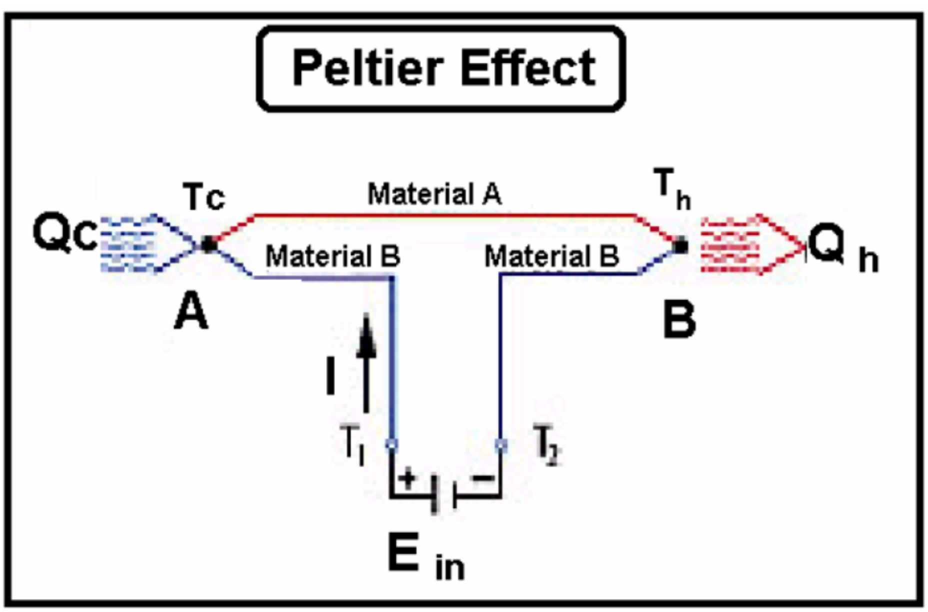
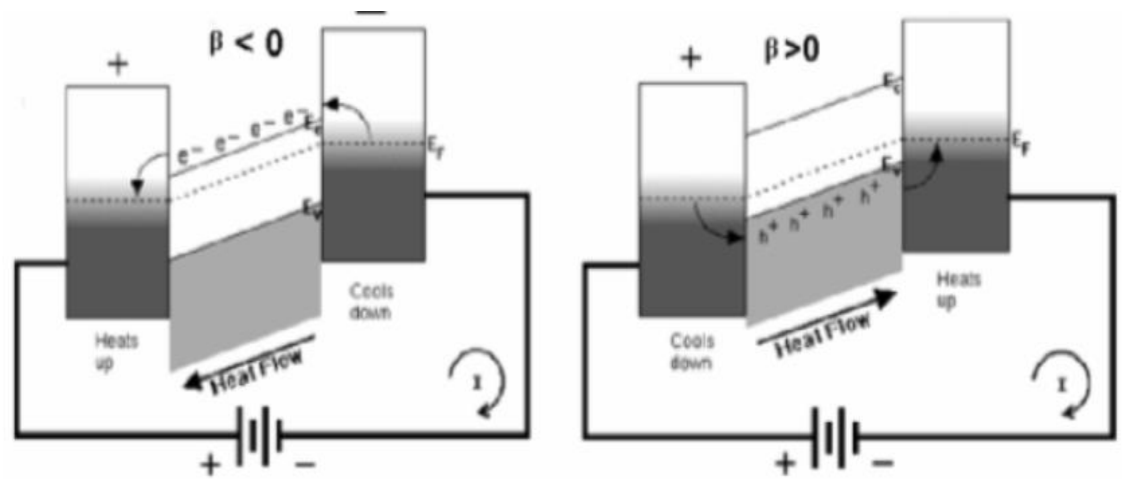


Figure 2.2 Principle of Peltier effect

➢ Peltier coefficient β has important effect on Thermoelectric cooling as following:

a) β <0; Negative Peltier coefficient High energy electrons move from right to left. Thermal current and electric current flow in opposite directions.

b) β >0; Positive Peltier coefficient High energy holes move from left to right. Thermal current and electric current flow in same direction.



a) -ve Peltier coefficient b) +ve Peltier coefficient

Figure 2.3 Effect of Peltier coefficient on cooling Process

2.5 Thermoelectric Principle of Operation

The typical thermoelectric module is manufactured using two thin ceramic wafers with a series of P and N doped bismuth-telluride semiconductor material sandwiched between them as shown in Figure2.4.

The ceramic material on both sides of the thermoelectric add rigidity and the necessary electrical insulation. The N type material has an excess of electrons, while the P type material has a deficit of electrons. One P and one N make up a couple, as shown in Figure2.5. The thermoelectric couples are electrically in series and thermally in parallel. A thermoelectric module can contain one to several hundred couples.

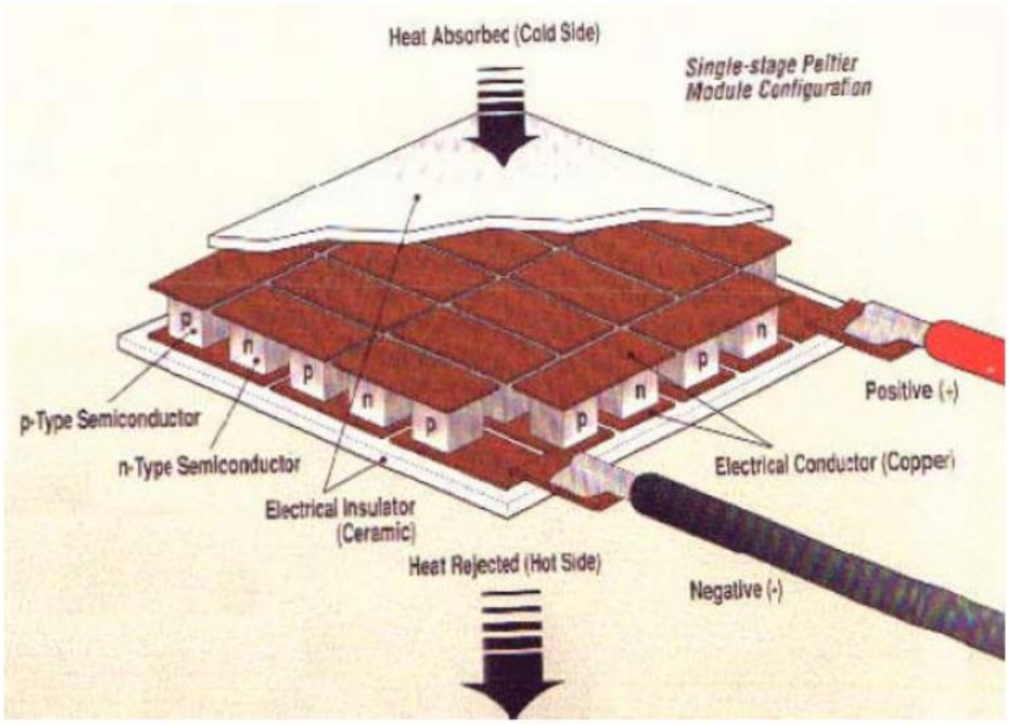


Figure 2. 4 TEC Principle of operation

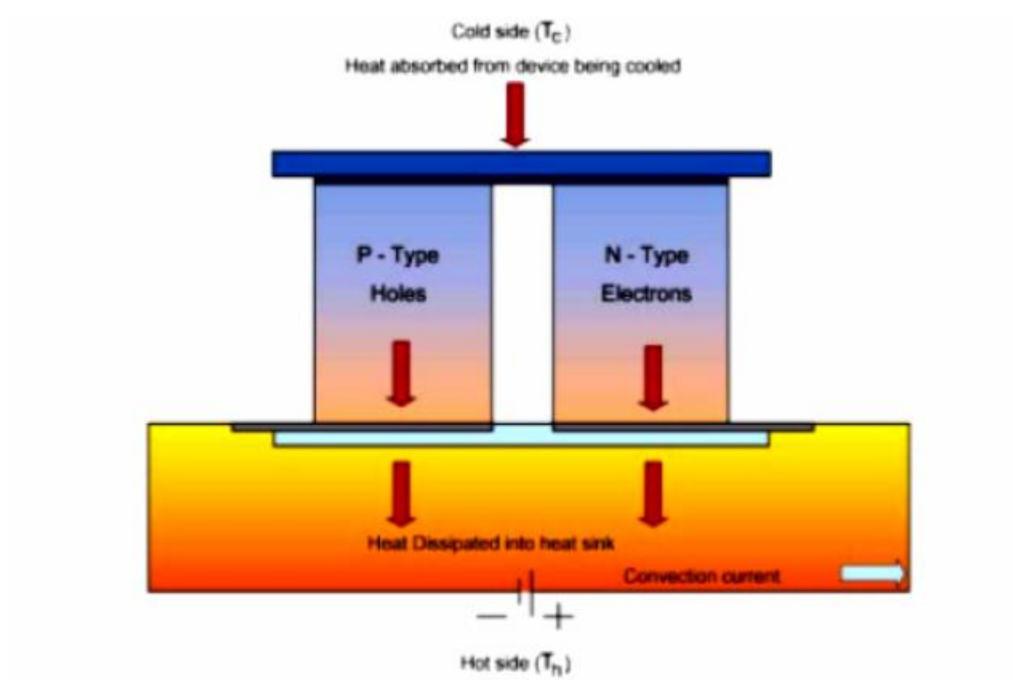


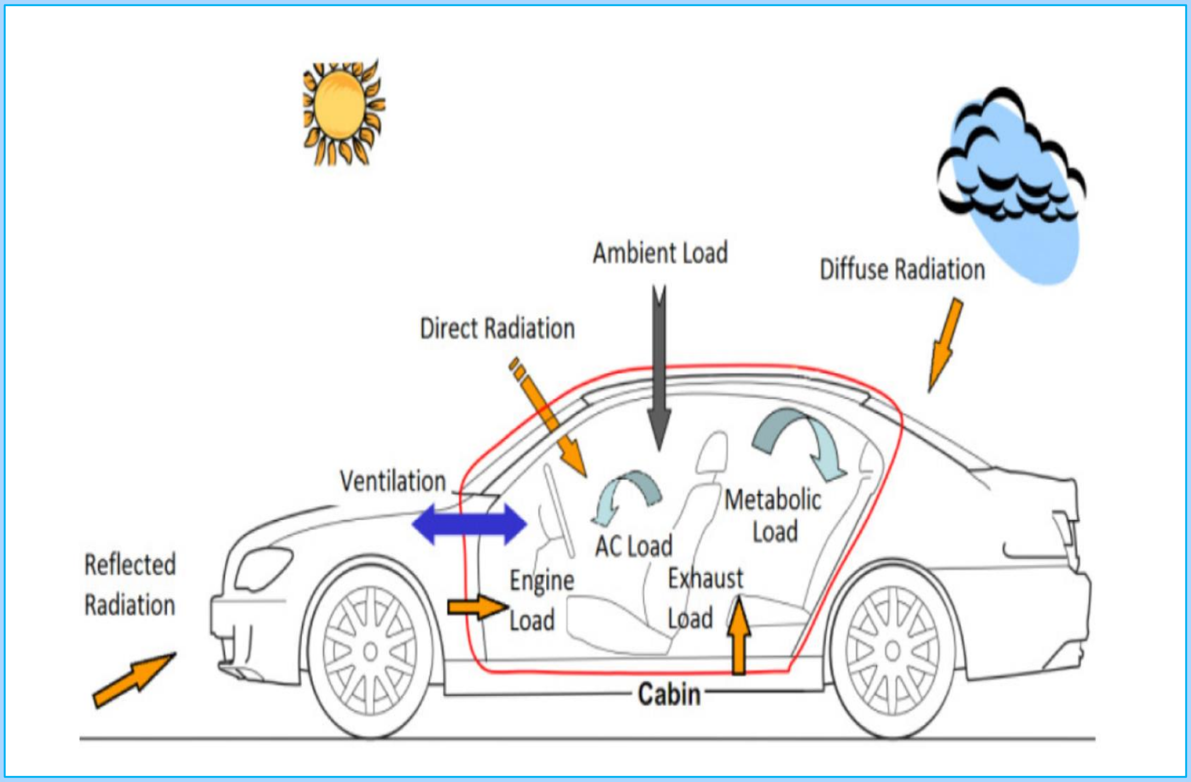
Figure 2.5 Working Principle of a thermoelectric cooler

As the electrons move from the P type material to the N type material through an electrical connector, the electrons jump to a higher energy state absorbing thermal energy (cold side). Continuing through the lattice of material; the electrons flow from the N type material to the P type material through an electrical connector dropping to a lower energy state and releasing energy as heat to the heat sink (hot side).

Thermoelectric can be used to heat and to cool, depending on the direction of the current. In an application requiring both heating and cooling, the design should focus on the cooling mode. Using a thermoelectric in the heating mode is very efficient because all the internal heating (Joulian heat) and the load from the cold side is pumped to the hot side. This reduces the power needed to achieve the desired heating.

CHAPTER-3

LOAD CALCULATION



3.1 Metabolic Load:

- The metabolic activities inside human body constantly create heat and humidity (*i.e.* perspiration). This heat passes through the body tissues and is finally released to the cabin air. This amount is considered as a heat gain by the cabin air and is called the metabolic load. The metabolic load can be calculated by

$$Q_{met} = \sum_{Passengers} MA_{DU}$$

Where M is the passenger's metabolic heat production rate.

(It is assumed from ISO 8996 based on various criteria for driver: M = 85 W/m^2, Passenger: M = 55 W/m^2)

Here, A_{DU} is the estimation of the body surface area,

$$A_{DU} = 0.20(W)^{0.425}\,(H)^{0.725}$$

(W and H are weight and height; For average: W = 70kg, H = 1.75m)

$$A_{DU} = 0.20(70)^{0.425}\,(1.75)^{0.725}$$

$$A_{DU} = 1.85\ m^2$$

$$Q_{met} = \sum MA_{DU}$$

$$= 85\ (1.5) + 4\ (55)\ (1.85)$$ (1 driver and 4 passengers)

$$= 564.25\ W$$

3.2 Radiation Load:

- The heat gain due to solar radiation is a significant part of the cooling loads encountered in vehicles. According to ASHRAE [7], solar radiation heat load can be categorized into direct, diffuse, and reflected radiation loads. Direct radiation is that part of the incident solar radiation which directly strikes a surface of the vehicle body, which is calculated from

- Direct radiation:

$$Q_{Dir} = \sum_{Surface} S\ \tau\ \dot{Z}_{Dir}\ COS\theta$$

(S is surface area, $\dot{Z}_{Dir}$ is direct radiation heat gain per unit area, Q is angle between surface element & position of sun in sky, τ is the surface transmissivity)

Latitude angle l = 23^0
Hour angle = 0^0
Declination = + 23.5^0 (21st June)

$= -23.5^0$ (21st December)

Tilt angle = 45^0

$\xi = 0^0$

Reflectivity of glass = 0

- Altitude angle β at solar noon

  $\beta_{max} = \Pi/2 - [\, l - a \,]$

  $= 89.53^0$

At noon solar azimuth angle

$Y = 0^0$

Glass solar azimuth angle

$\alpha = 180^0 - (y + \xi)$

$= 180^0$

Now inclination angle

$\theta_{inc} = COS^{-1}(COS\beta \; COS\alpha)$

$= 89.5^0$

Direct radiation:

$I_{Dir} = A / \exp\left(\frac{-B}{sin\beta}\right)$

(A and B are constants: From ASHRAE Book A = 1080, B = 0.21)

$I_{Dir} = 1080 / \exp\left(\frac{-0.21}{sin89.3}\right)$

$I_{Dir} = 875.4 \; W/m^2$

$Q_{Dir} = \sum_{Surface} S \; Ʈ \; \dot{Z}_{Dir} \; COS\theta$

For vehicle body, I = 0

For glass, I = 0.5

$= \sum_{glass} S \; Ʈ \; \dot{Z}_{Dir} \; COS\theta$

$= (342)(0.5)(875.4) \; COS45$

$= 1058.5 \; W$

- Diffuse Load

$Q_{Dif} = \sum_{Surface} S \; Ʈ \; \dot{Z}_{Dif}$

Where, $\dot{Z}_{Dif} = C\ \dot{Z}_{Dir}\ \frac{1+cos\xi}{2}$ (C = 0.135, ξ = tilt angle of surface = 45^0)

$= 0.135\ (875.4)\ \frac{1+cos45}{2}$

$= 100.81\ W/m^2$

Q_{Dif} = (3.42) (0.5) (100.81)

= 172.38 W

- Reflected radiation

$$Q_{Ref} = \sum_{Surface} S\ \tau\ \dot{Z}_{Ref}$$

Where, $\dot{Z}_{Ref} = (\dot{Z}_{Dir} + \dot{Z}_{Dif})\ (\rho_g)\ \frac{1-cos\xi}{2}$ (where ρ_g is ground reflection and ρ_g = 0.6)

= (875.4 + 100.81) (0.6) (0.15)

$= 87.86\ W/m^2$

Q_{Ref} = (342) (0.5) (87.86)

= 150.241W

$Q_{Radiation} = Q_{Dir} + Q_{Dif} + Q_{Ref}$

= 1058.5 + 172.38 + 150.24

= 1381.2 W

3.3 Ambient Load

- The ambient load is the contribution of the thermal load transferred to the cabin air due to temperature difference between the ambient and cabin air. Exterior convection, conduction through body panels, and interior convection are involved in the total heat transfer between the ambient and the cabin. Equation given below shows the general form of the ambient load model.

$$Q_{Amb} = \sum_{Surface} S\ U\ (T_s - T_i)$$

Where, U is overall heat transfer co-efficient of surface element.

T_s and T_i are average surface temperature and average cabin temperature respectively.

Here,

$$\frac{1}{U} = \frac{1}{ho} + \frac{1}{hi} + \frac{\lambda}{k}$$

Where, h_i and h_o are outside and inside thermal conditions.

k is surface thermal conductivity.

λ is thickness of surface element.

We can find h_i and h_o from

$h = 0.6 + 6.64\sqrt{v}$ (v is velocity of vehicle in m/s)

$h_o = 27.71$

$h_i = 7.24$ (we assume v = 60km/h = 16.6m/s)

k is conductivity of glass = 1.05, $\lambda = 1X10^{-2}$

$$\frac{1}{U} = \frac{1}{27.71} + \frac{1}{7.24} + \frac{1X10-2}{1.05}$$

U = 5.43

$Q_{Amb} = \sum_{Surface} S\, U\, (T_s - T_i)$ ($T_s = 40^0C$ and $T_i = 21^0C$)

= 3.42 (5.43) (40-21)

= 352.8 W

3.4Exhaust Load

- Conventional and hybrid electric vehicles have an Internal Combustion Engine (ICE) that creates exhaust gases. The Exhaust Gas Temperature (EGT) can reach as high as 1000^0C. Because of the high temperature of the exhaust gas, some of its heat can be transferred to the cabin through the cabin floor. Considering S_{Exh} as the area of the bottom surface in contact with the exhaust pipe, the exhaust heat load entering the cabin can be written as

$Q_{Exh} = S_{Exh}\, U\, (T_{Exh} - T_i)$

T_{Exh} = 0.138 (RPM) -17

= 0.138 (700) -17

= 80

S_{Exh} = 1.7

U = 1.61 which is overall heat transfer co-efficient.

= 161.48

3.5 Engine Load

- Similar to the exhaust load above, the high temperature engine of a conventional or hybrid car can also contribute to the thermal gain of the cabin. Equation given below shows the formulation used for calculating the engine thermal load.

$Q_{Eng} = S_{Eng}\, U\, (T_{Eng} - T_i)$

$T_{Eng} = -2 \text{ X } 10^{-6} (RPM)^2 + 0.0355 \text{ RPM} + 77.5$

$T_{Eng} = -2 \text{ X } 10^{-6} (700)^2 + 0.0355 (700) + 77.5$

= 102.25 - 0.98

= 101.27

U can be assumed from car material as 4.5.

$S_{Eng} = 0.57m^2$

Q_{Eng} = (0.57) (4.5) (101.27)

= 259.75 W

3.6 Ventilation Load

- Fresh air is allowed to enter the vehicle cabin to maintain the air quality for passengers. As the passengers breathe, the amount of CO2 concentration linearly increases over time. Thus, a minimum flow of fresh air should be supplied into the cabin to maintain the passengers comfort. Arndt and Sauer reported the minimum fresh air requirements for different numbers of passengers in a typical vehicle. For instance, a minimum of 13% fresh air is needed for a single passenger. For a small sedan car at a pressure difference of 10 *Pa*, a leakage of 0.02 *m3/s* was reported. Because of the air conditioning and ventilation, the cabin pressure is normally slightly higher than the ambient. Thus, the ventilation load has to take the leakage air flow rate into account. Meanwhile, in the steady-state operation, the built- up pressure is assumed to remain constant. Hence, ambient air is assumed to enter the cabin at the ambient temperature and relative humidity, and the same flow rate is assumed to leave the cabin at the cabin temperature and relative humidity. According to psychrometric calculations, ventilation heat gain consists of both sensible and latent loads. To account for both these terms, assuming a known flow rate of fresh air entering the cabin, the amount of thermal heat gain can be calculated from

For inside condition

Temperature is 21^0 C and 50% R.H.

W_i = 0.0093 kg N/kg h_i = 47.656 kJ/kgH

For outside condition

Temperature is 40^0C.

W_i = 0.01599 kg N/kg h_i = 78.875 kJ/kgH

V_0 = 0.895 m^3 / kg (ventilation load)

We know that for a single person a ventilation load required is

= 3.5 l/s

Overall ventilation required is

V_{ov} = 3.5 (5) = 17.5 l/s = 17.5 m^3/s

Air flow rate is 0.01 m^3/s.

Hence mass flow rate of ventilation is = (17.5 X 10^{-3})/(0.01)

m = 1.75 = $m_{overall}$

Q_{sv} = 1.75 (1.021) (40.21)

= 33.97 W

Q_{iv} = $m_{overall}$ h_{fg} (w_o – w_i)

= (1.75) (0.01594-0.0093) (24.983)

= 29.06 W

$Q_{ventilation}$ = Q_{iv} + Q_{sv} = 33.87 + 29.06 = 63.03 W

3.7 Total Load

- The summation of all the load types will be the instantaneous cabin overall heat load gain. The mathematical formulation of the model can thus be summarized as

$Q_{total} = Q_{met} + Q_{air} + Q_{Dif} + Q_{Ref} + Q_{Amb} + Q_{Ext} + Q_{Eng} + Q_{ventilation}$
$= 564.25 + 1058.5 + 1720.38 + 150.24 + 352.8 + 161.48 + 259.75 + 63.03$
$= 2782.43$ W

- **AC Load:** The duty of the air conditioning system is to compensate for other thermal loads so that the cabin temperature remains within the acceptable comfort range. In cold weather conditions, positive AC load (heating) is required for the cabin. Inversely, in warm conditions, negative AC load (cooling) is needed for maintaining the comfort conditions. The actual load created by the AC system depends on the system parameters and working conditions. In this work, it is assumed that an AC (or heat pump) cycle is providing the thermal load calculated by

$Q_{AC} = -[Q_{total}]$
$= -(m_a c_a + DTM)(T_i - T_{comf})/t_c$

[Here, T_{comf} is target comfort temperature,
t_c is overall pull down temperature,
t_c can be defined as the temperature required for cabin,

$t_c = t_p / \ln[T_o - T_{comf}]$
T_o is initial cabin temperature,

From ASHARE standards $t_c = 600$
Assume $c_a = 1008$ kJ/kg, $m_a = 0.08$]

$Q_{AC} = -2782.45 – [(0.08)(1008)+5700](19)/600$
$= -2782.45 – 183.03$
$= -2965.5$ W

Here we have total air conditioning load $Q_{AC} = -2965.5$ W

Cooling is produced by a single thermoelectric couple.

Here we are using thermoelectric couple 0f 12V and 18A.

So cooling produced by each thermocouple,

Q_a = (12)(18) = 216W

So, Number of thermoelectric couple required

$$N = \frac{Total\ Air\ conditioning\ Load}{Cooling\ Capacity\ of\ Single\ Module}$$

$$= \frac{-2965.5}{216}$$

= 13.17

So It can be taken, 15.

Number of thermoelectric couple required is 15

Total cooling produced by this couple is

Q_{total} = (15) (216) = 3240W

Which is more than air conditioning load.

The Circuit used for TEC module is

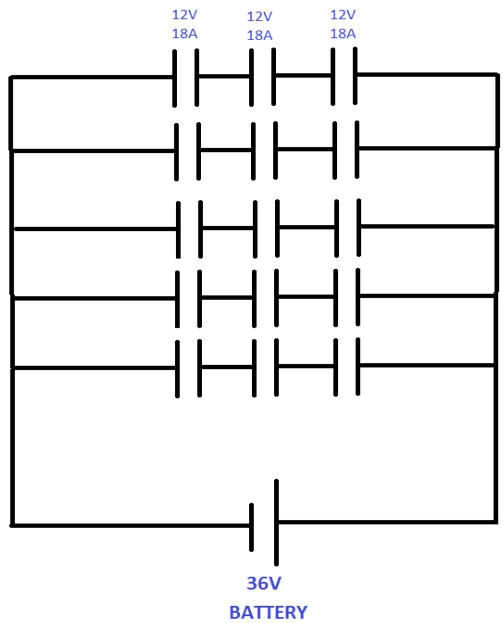


Figure 3.1 Circuit used for TEC Module

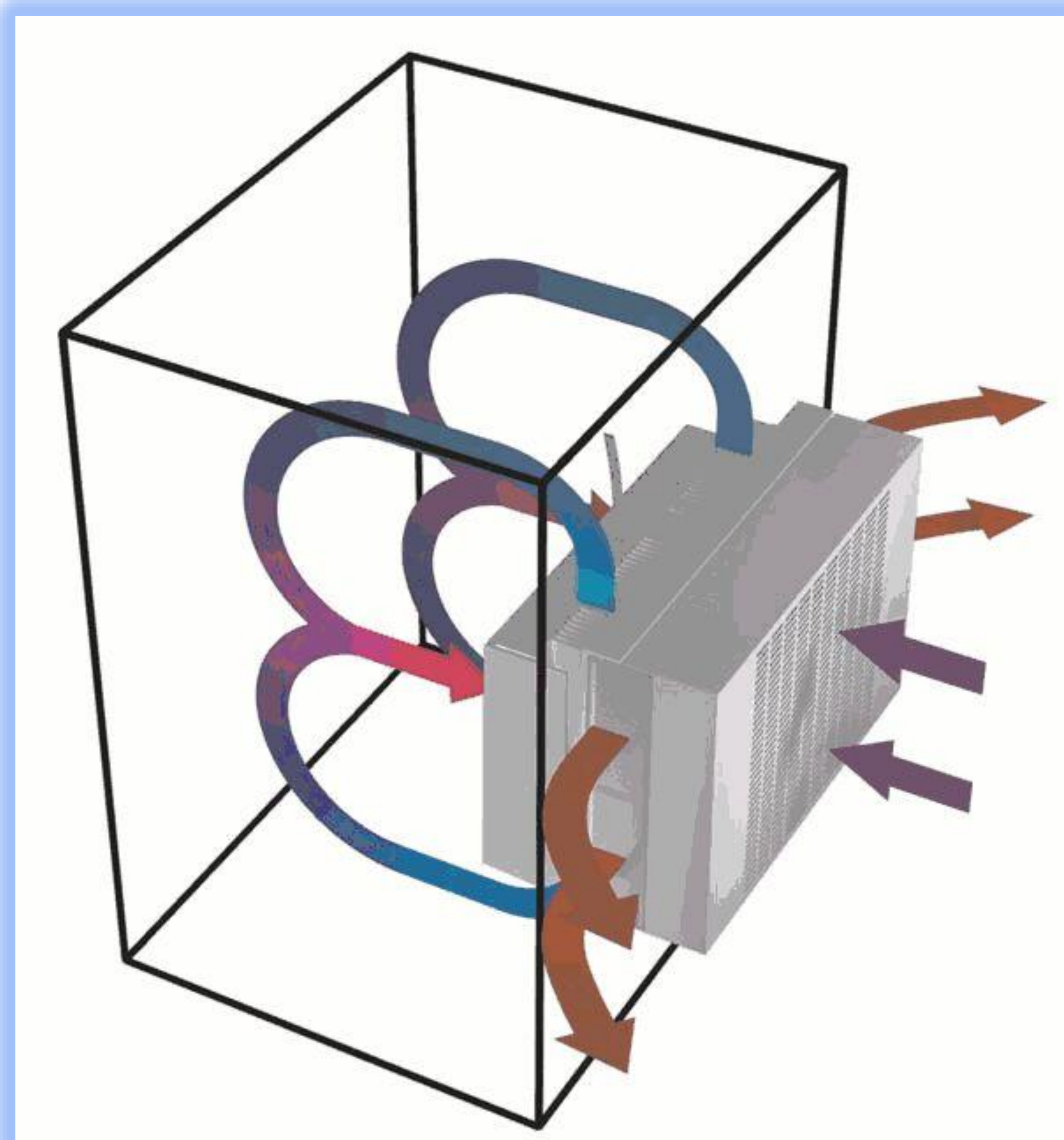
Total Voltage is V = 36 and Total current is I = 90A.

So, total power used is (36)(90) = 3240W

So, 15 TEC Modules are desired to be used.

CHAPTER-4

PERFORMANCE OF THERMOELECTRIC DEVICE



4.1 Figure of Merit

- The figure of merit is a method used to measure the performance of a thermoelectric device where it is equal to

$$Z = \frac{\alpha^2}{\rho k}$$

- where ρ is the electrical resistivity in Ohm-m and k is the thermal conductivity in W/mK.

- A higher   can result from higher α and/or lower   and k. These parameters depend on the type of material at a given temperature where it can be shown as dimensionless number. Therefore, in order to have a higher TE performance, a material with higher value should be used. Bismuth Telluride (Bi_2Te_3) is one of the most widely used bulk materials for thermoelectric cooler (TEC) applications due to its high figure of merit at room temperature. Other bulk materials such as Lead Telluride (PbTe) are also found in TE modules especially for higher temperature and thermoelectric generators (TEG) applications.

- With the aim of obtaining higher   values, nano-materials have been investigated where can be higher than one. The use of nanotechnology is to either increase the power factor which is the Seebeck coefficient and electrical conductivity, or to decrease the thermal conductivity which consists of electronic and lattice thermal conductivities. The Seebeck coefficient and electrical conductivity are usually related inversely, which makes it more complicated to increase any of them. Moreover, decreasing the thermal conductivity will increase the electrical conductivity due to the constant relationship between the electrical conductivity and electronic thermal conductivity, i.e., the Lorentz number. Hence, the lattice thermal conductivity, which is the only parameter that is almost independent of the electronic structure, can be reduced by manipulating the phonon scattering. Figure 5.1 presents state-of-the-art of the dimensionless figure of merit of the old and new thermoelectric material. It can be seen from the figure that bismuth telluride has the highest figure of merit for bulk material at room temperature. Also, nano-material shows a noticeable improvement that provides a higher figure of merit. Figure 4.1 Plot of state-of-the-art of the figure of merit vs. temperature of thermoelectric materials.

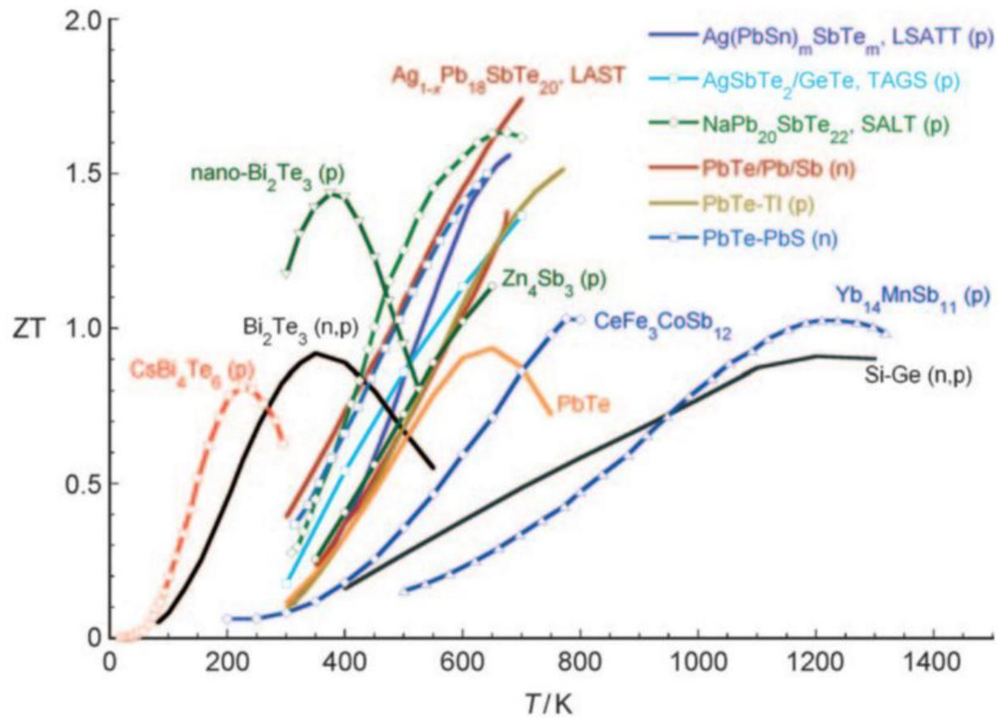


Figure 4.1 Plot of state-of-the-art of the figure of merit vs. temperature of thermoelectric materials

4.2 Optimum Design of Thermoelectric System

- The state-of-art related projects of thermoelectric parameters, on the other hand, need to be addressed in order to investigate their optimum design. Literature shows serval general methods (or in a different areas) on how to optimize thermoelectric parameters. Analyzing the product of the number of thermocouples, the element geometric ratio, and the thermal conductivity, which is defined as the thermal conductance of elements, is a very practical way to assist studying the optimum design of the thermoelectric parameters. The literature also showed some techniques that can help analyze the optimum design of the thermoelectric parameters.

- Dimensionless parameters for a thermoelectric cooler system were introduced by Yamanashi in order to optimize thermoelectric parameters. The paper studied the effect of different dimensionless parameters on the TEC performance as a function of dimensionless electrical current. One of the highlights of this paper is to show that the thermal resistance of the hot side of the TEC has a greater impact on the performance than the cold side thermal resistance. Furthermore, this technique gives the ability to obtain the maximum COP when the heat exchanger of the TEC system is provided. Even though the Yamanashi technique is not very adoptable due to the difficulties in obtaining the optimum parameters for the cooling power, some researchers applied it and provide

39 useful results. In fact, Xuan was able to use the Yamanashi method to optimize the length of the element while Pan studied the optimum design of cooling power for a thermoelectric cooler.

- There are also more studies on the investigation of the optimum design of thermoelectric system but applying these methods does not seem very practical. One example is the comparison of the power density of the waste exhaust heat recovery when using a thermoelectric generator system. For similar inputs, the reported power densities of Hsu, Karri and New Energy and Industrial Technology Development Organization (NEDO) are 0.032 W/cm^2, 0.61 W/cm^2, and 1W/cm^2, respectively. These variations in the power densities raised the question of the availability of the optimum design of the thermoelectric system.

- Lately, Lee developed an optimal design method that uses the dimensional analysis to optimize the thermoelectric generator and cooler parameters. For thermoelectric cooler, the method gives the ability to optimize the electrical current and the geometric ratio (thermo-element cross sectional area by its length) simultaneously at a given figure of merit, ambient temperatures, and heat sink parameters. This method will be adopted in the current study in order to develop the optimum design of the TEAC which will be discussed in the next chapter.

4.3 Performance Curve

- The cooling capacity was conducted at an ambient temperature of 35°C. Performance will deviate based on ambient temperature condition.

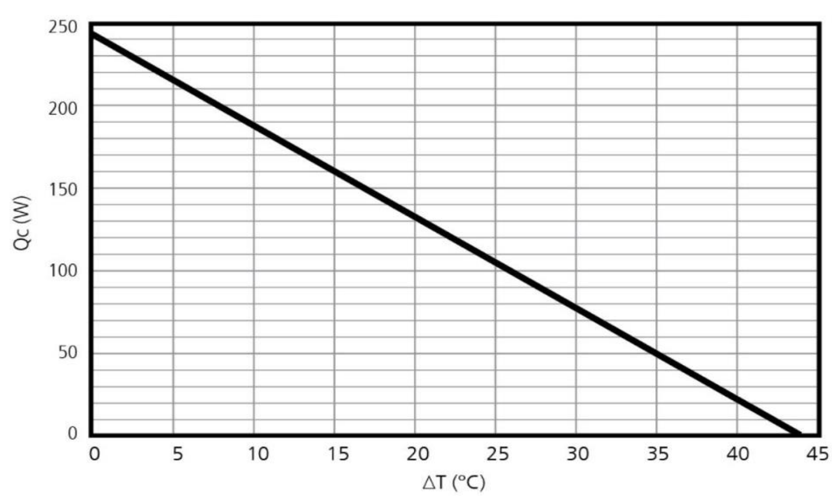


Figure 4.2 Performance Curve

4.4 Comparison between Thermoelectric Air Conditioning and Traditional Compressor System

Comparing factor	Thermoelectric cooler	Compressor Cooler
Size	Small	Big
Weight	5kg to 8kg	10kg to 15kg
Accessories/ pipeline	Less	More
Environmental protection	No refrigerant	Need refrigerants
Orientation	No limit	With limit
Moving Parts	No moving parts	With moving parts
Reliability	> 100,000 hr	< 40,000 hr

Table 4.1 Comparison between Thermoelectric Air Conditioning and Traditional Compressor System

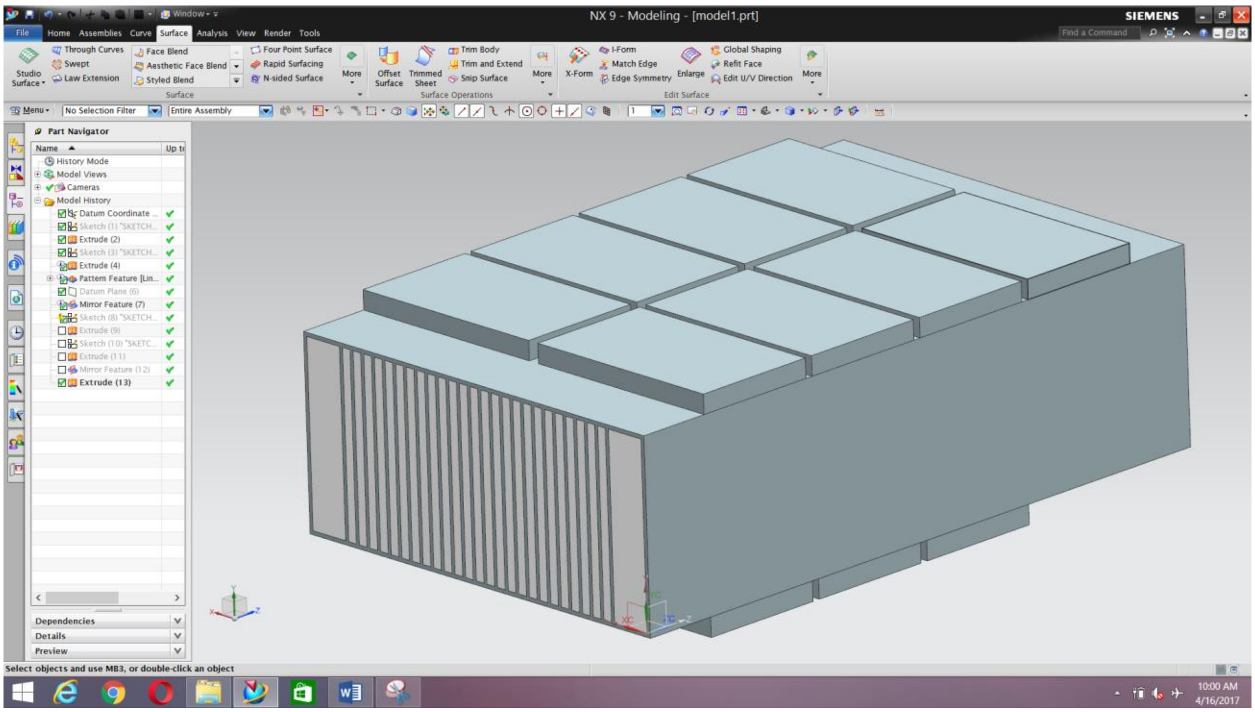
CHAPTER-5

MODELLING AND ANALYSIS

5.1 NX Design Software Model

Size of Duct	22cm*9.5cm*35cm
Size of Heat Sink	27.6cm*5cm*0.2cm
No. of Fins	25
Spacing	5cm
Thickness of Sheet	0.2cm

Table 5.1 Dimensions of Model



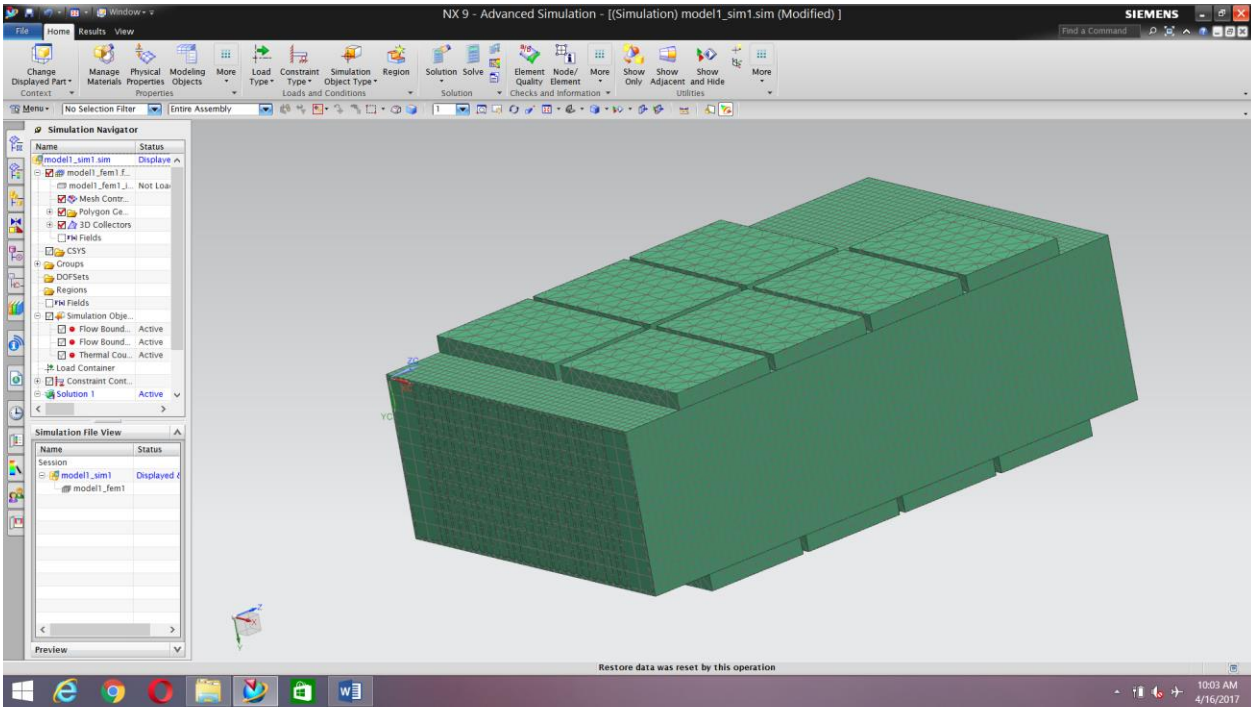
5.2 Assigning the Material and Meshing

Part	No. of Parts	Material
Duct	1	Aluminum 6061
Thermoelectric Couples	15	Bismuth Telluride

Table 5.2 Selection of Material

Part	Material	Mesh	Element Family	Elements	Nodes
Duct	Pure Substance , Aluminum_6061	3d_mesh	Hex20	45920	307486
Air	Pure Substance , Air	3d_mesh	Hex20	10150	80340
Thermoelectric couple	Pure Substance , Bismuth Tellurium	3d_mesh	Tetra10	6030	13815

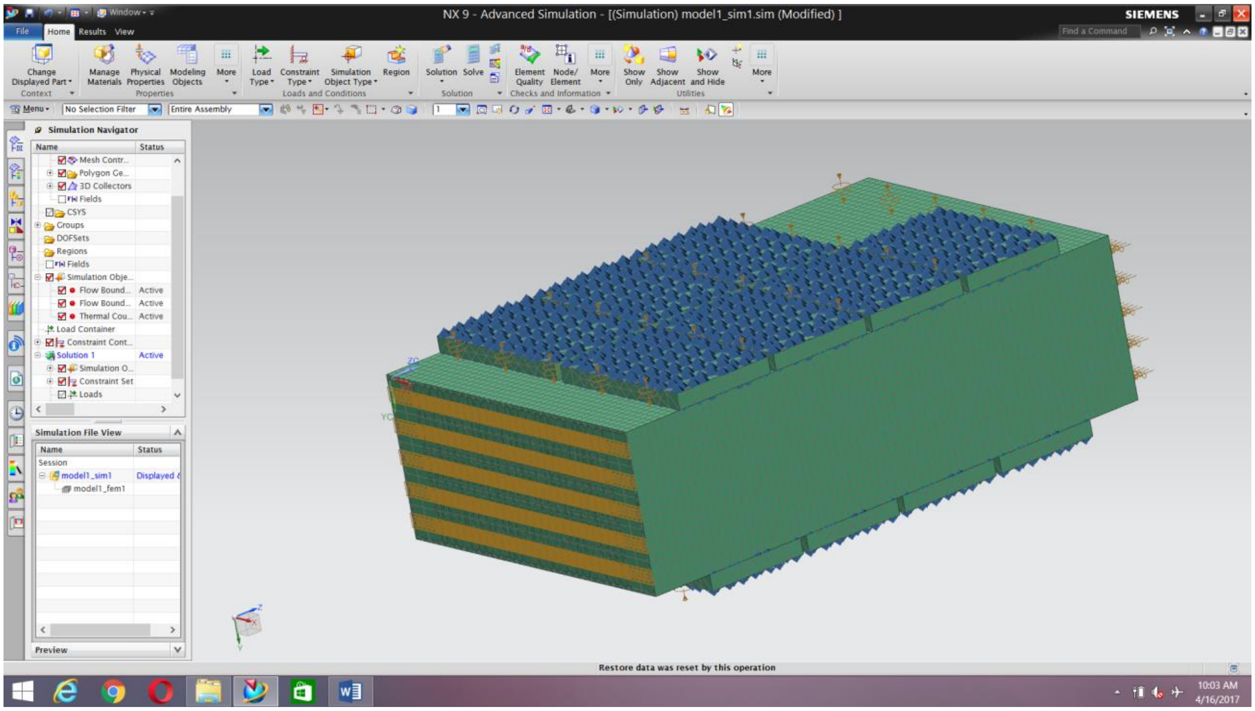
Table 5.3 Selection of Mesh



5.3 Loads and Boundary Conditions

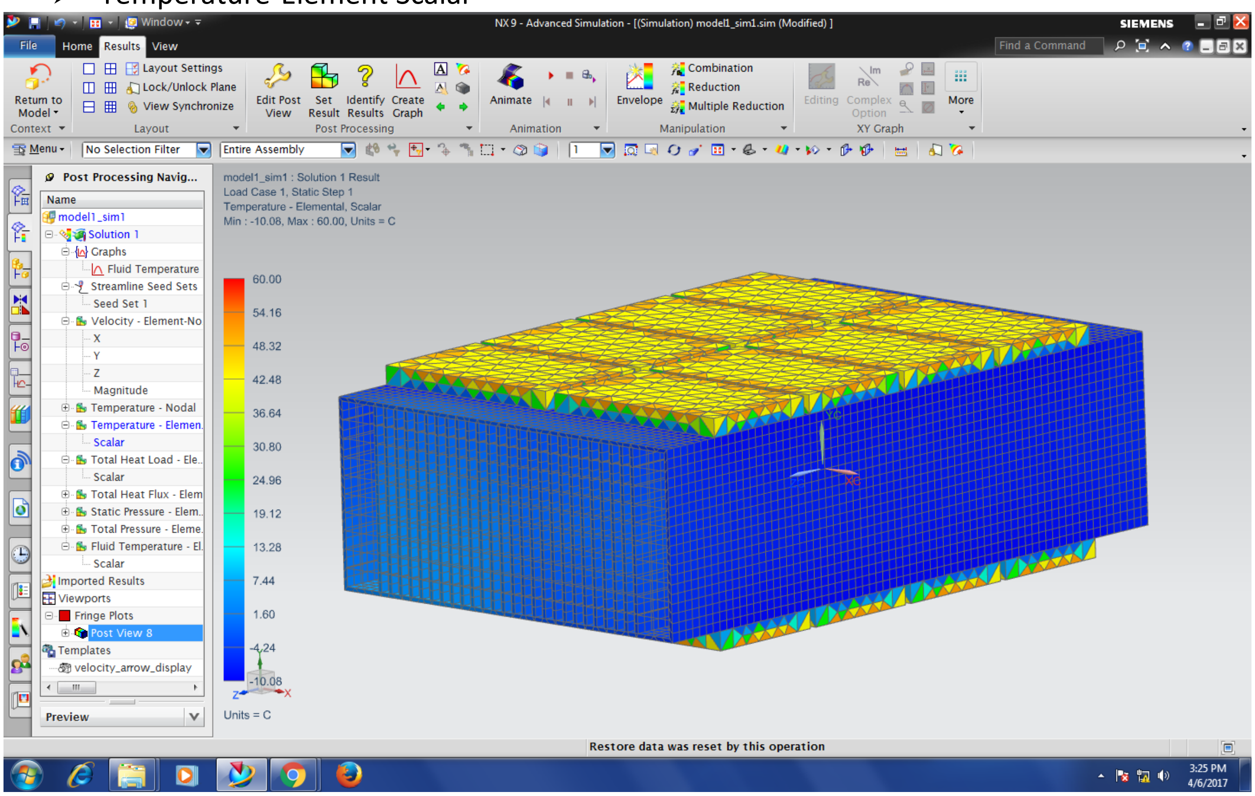
- Constraints:
  - Temperature of outer side of TEC: 60°C
  - Temperature of outer side of TEC:20°C
  - Convection to Environment: Ambient

- Simulation Objects:
  - Air Flow Velocity: 2.06 m/s
  - External Pressure: Ambient
  - Thermal conductivity of Thermal Coupling Between TEC and Duct: 1.2 W/mK

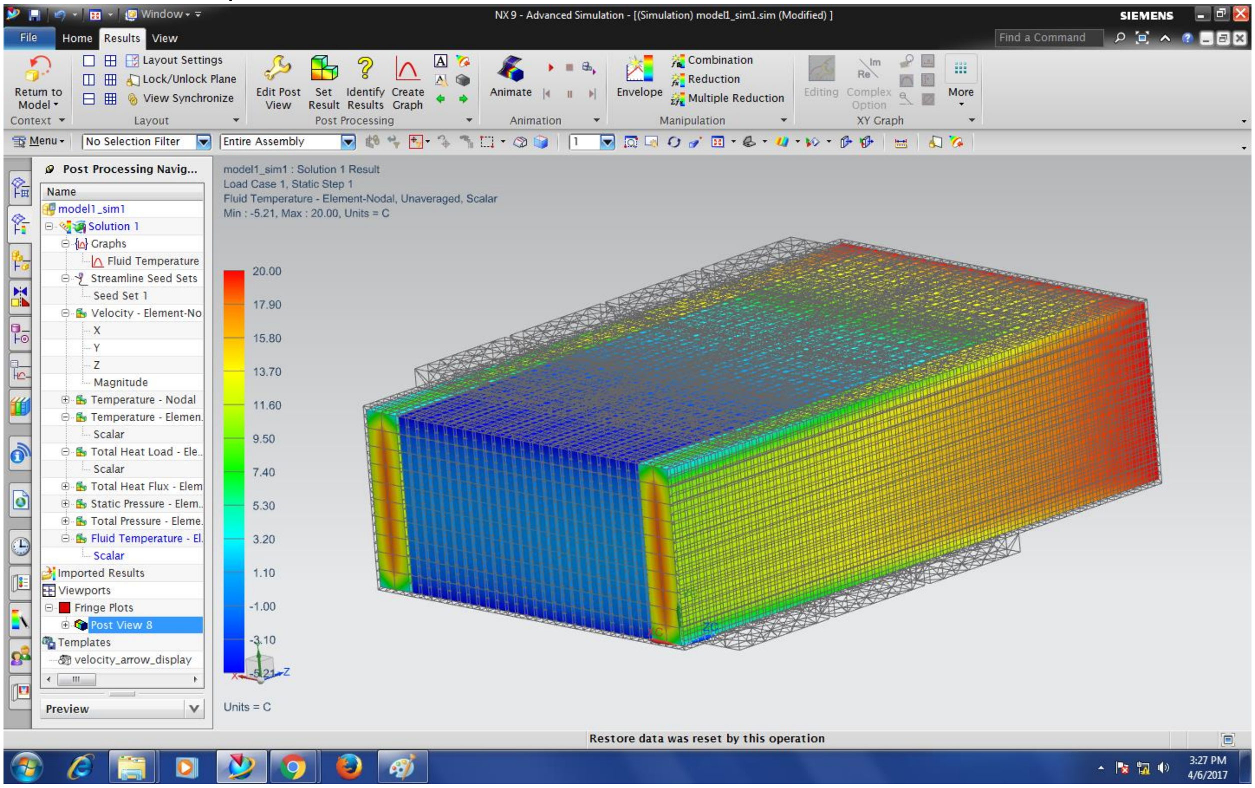


5.4 Results for Inlet Air Temperature of 20°C

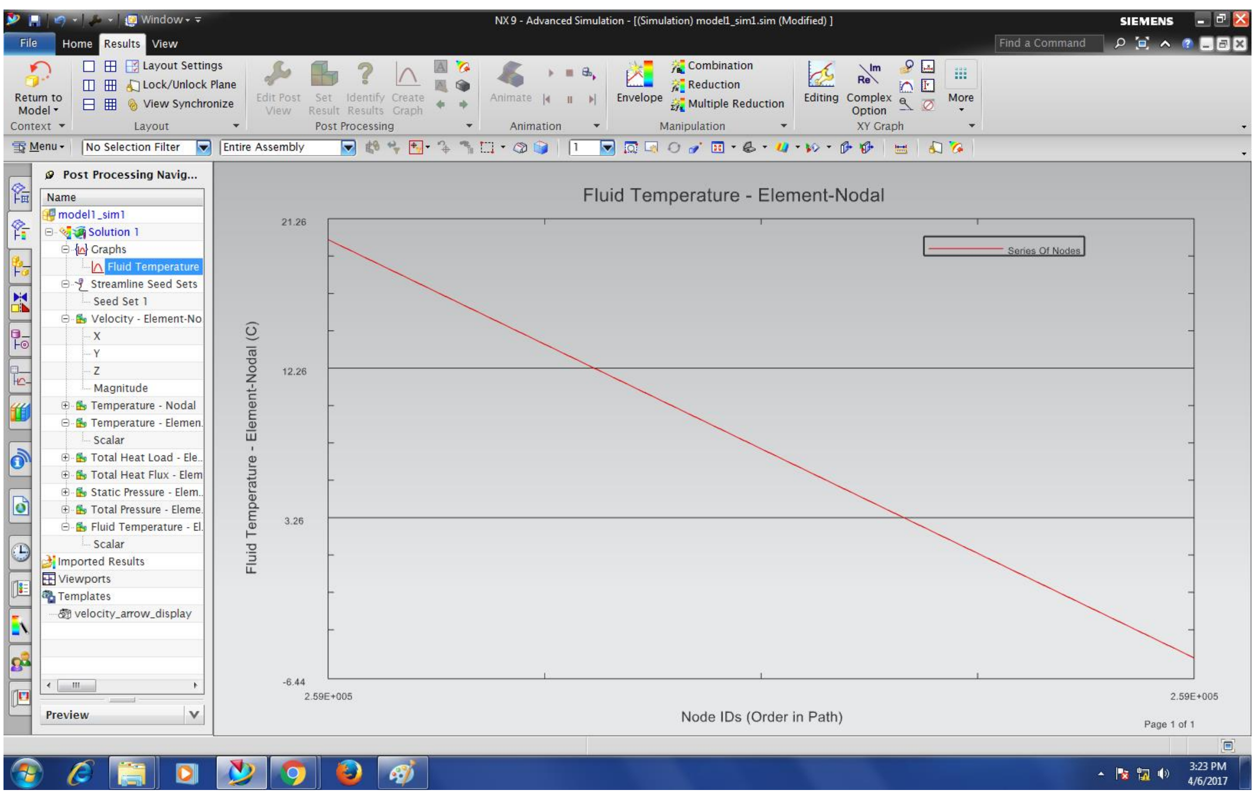
- ➢ Temperature-Element Scalar



➢ Fluid Temperature-Element Scalar

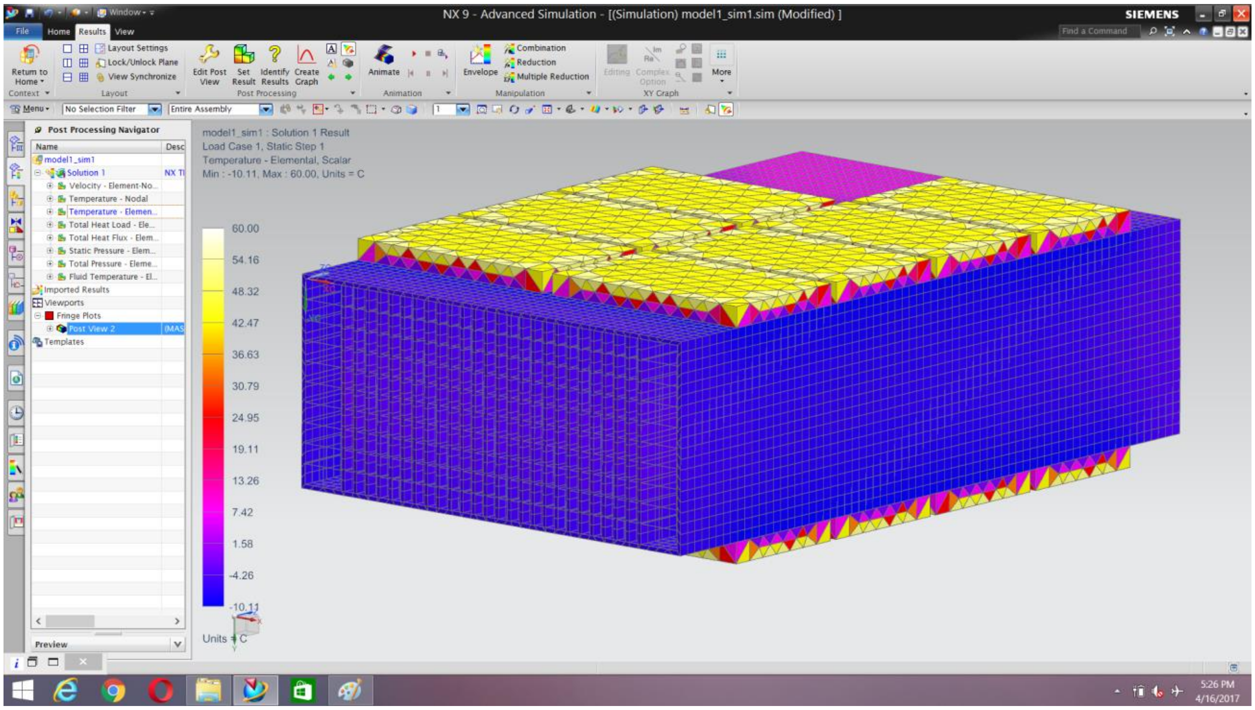


➢ Fluid Temperature Plot

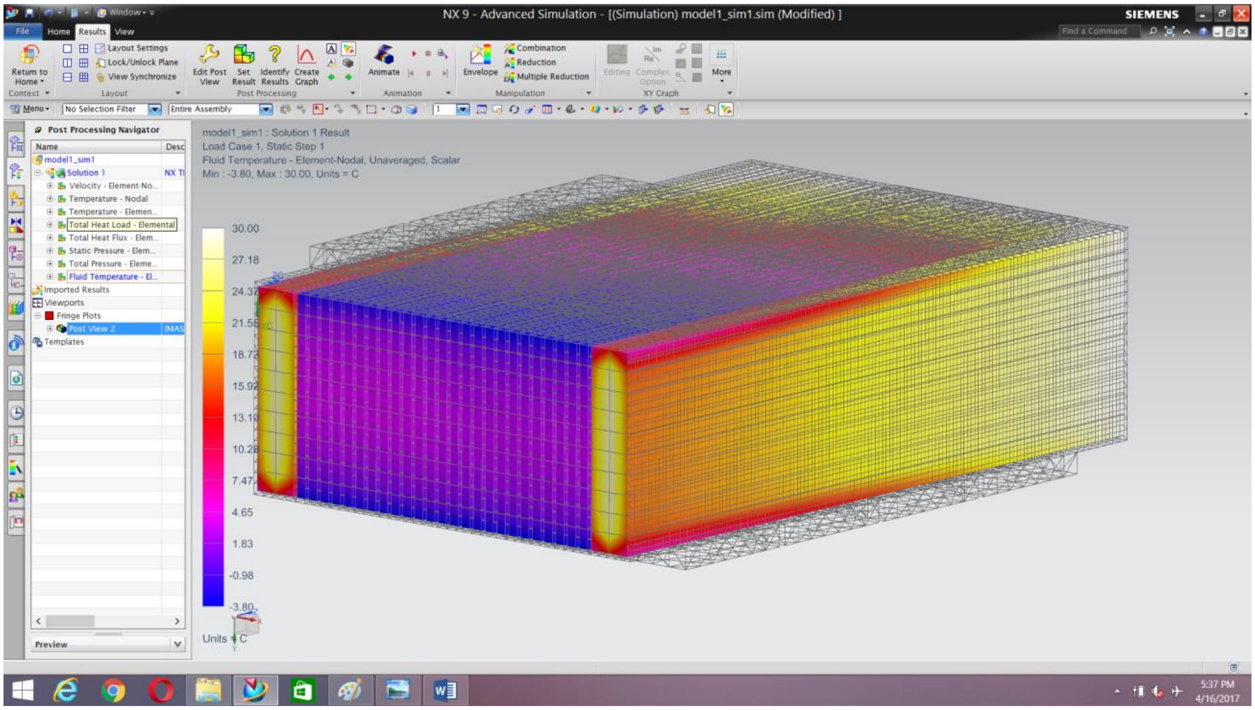


5.5 Results for Inlet Air Temperature of 30^{o}C

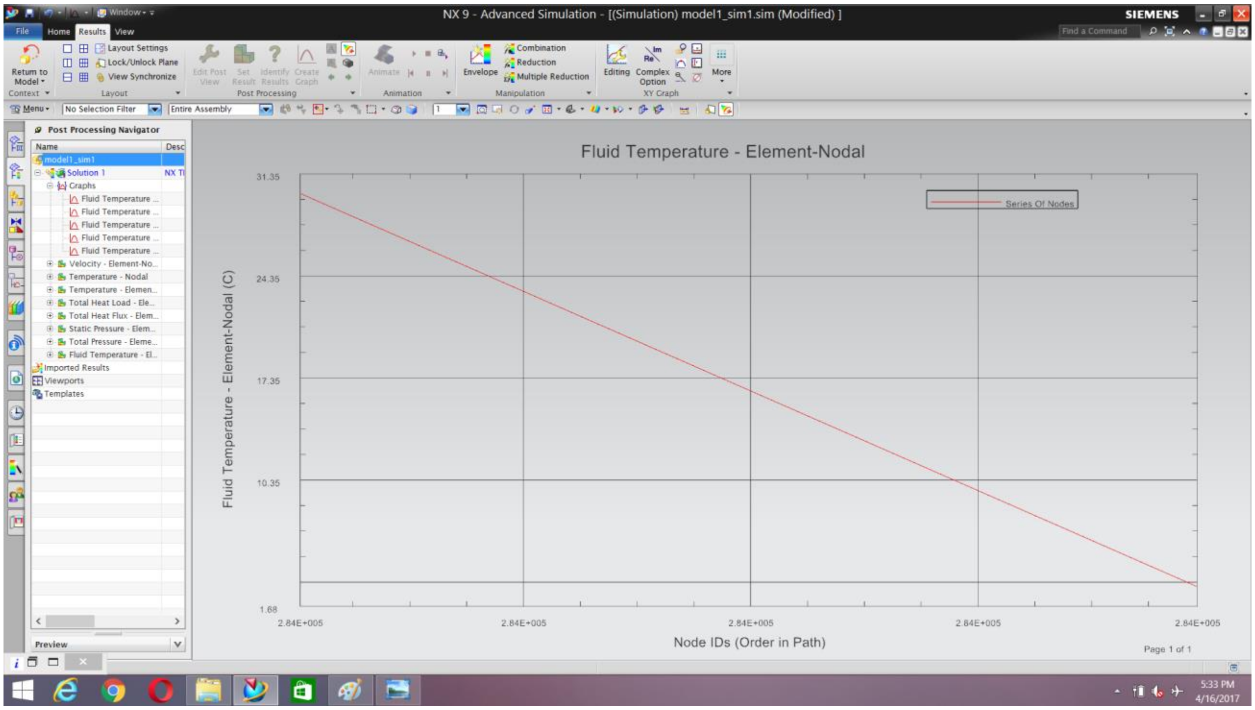
- Temperature-Element Scalar



- Fluid Temperature-Element Scalar

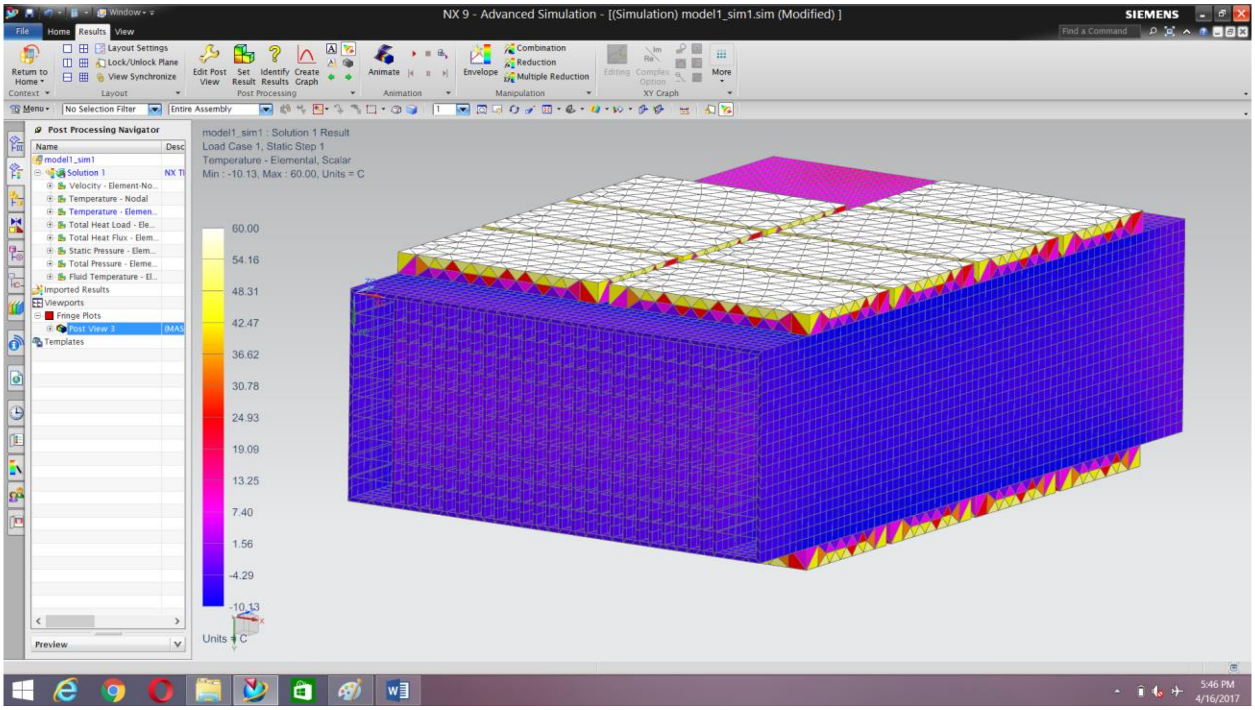


➢ Fluid Temperature Plot

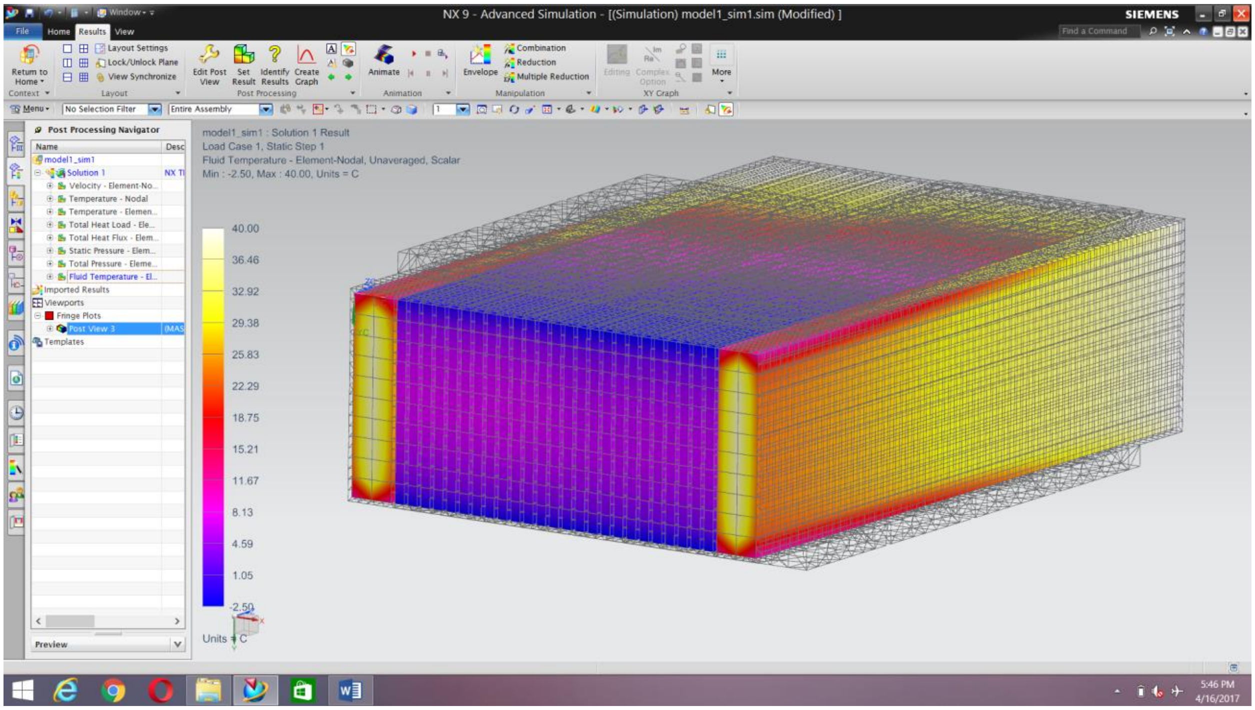


5.6 Results for Inlet Air Temperature of 40°C

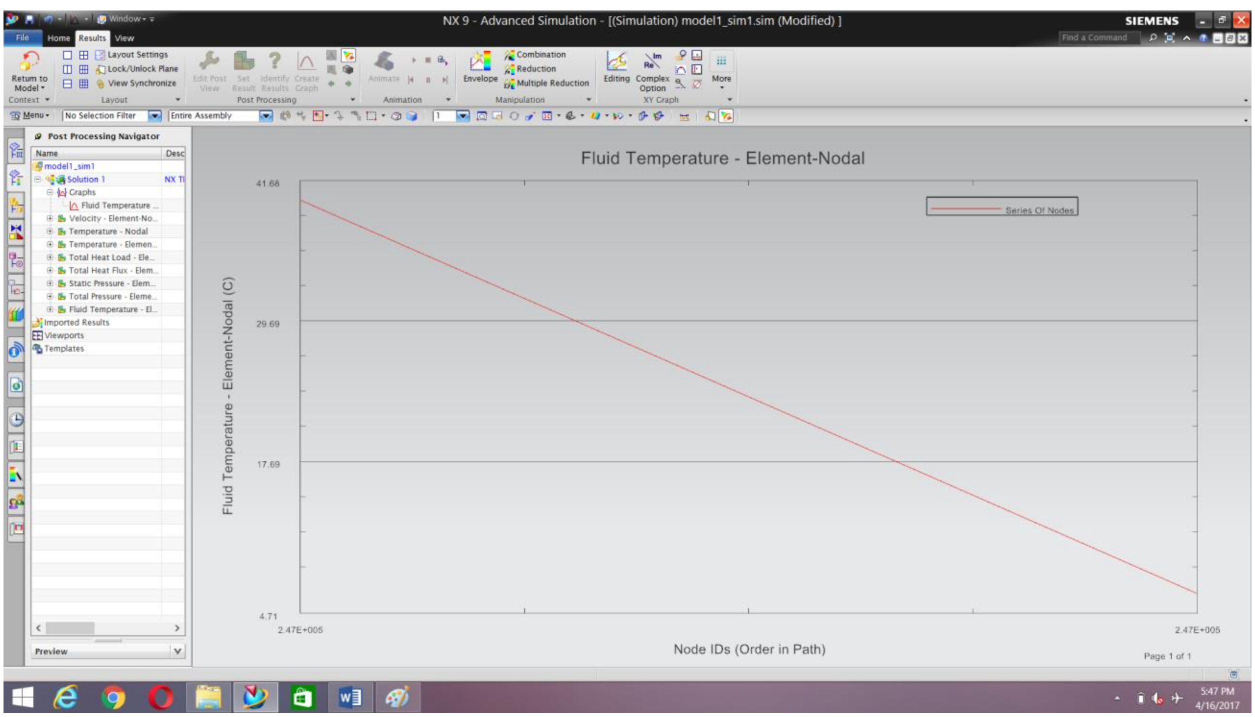
➢ Temperature-Element Scalar



- ➢ Fluid Temperature-Element Scalar



- ➢ Fluid Temperature Plot



CHAPTER-6

EXPERIMENTAL MODEL

6.1 Fabrication Process

- A variety of processes are available for aluminum processing. The range of shielding gases is correspondingly wide.

- TIG welding:
  For better removal of the oxide coating, TIG welding is carried out using alternating current. In addition to classic argon and the argon-helium mixes, the more advanced dual and triple gas mixes Aluline N and Aluline He N are available as shielding gases. The nitrogen content of Aluline N stabilizes and concentrates the arc and improves the penetration properties. The TIG DC mode with a negative electrode is relatively seldom used. Here, helium or a high helium content shielding gas is employed.

- MIG welding:
  In most cases, pulse technology is to be recommended. This means that thinner sheets can be welded while, at the same time, increasing the protection against pore formation. Spatters are also reduced. The range of gases is similar to that for TIG welding. The admixture of nitrogen in the Aluline N series has proven beneficial. With increasing sheet thickness, the helium content should be raised accordingly.

- Special techniques:
  Plasma welding with a positive electrode is a variety of TIG welding, usually applied in automated systems. The Plasma-MIG process, that combines plasma process with MIG welding, is also normally used with fully automation. Thick sheets can be welded in one position with very high quality in this mode. In the dual wire MIG technique, two wire electrodes, usually with two separate power sources, are mounted together in one torch. This is used, by preference, for the welding of long seams on level components or on circumferential welds.

	Group acc. ISO 14175	**Composition as a percentage by volume**		
		Ar	**He**	**N_2**
Welding Argon*	|1	100	-	-
Helium 4.6	|2	-	100	-
Aluline He15	|3	85	15	-
Aluline He15	|3	70	30	-
Aluline He15	|3	50	50	-
Aluline He15	|3	30	70	-
Aluline He15	|3	10	90	-
Aluline N	Z	Balance	-	0,015
Aluline He15 N	Z	Balance	15	0,015
Aluline He15 N	Z	Balance	30	0,015
Aluline He15 N	Z	Balance	50	0,015

* A minimum purity of 4.6 should/can be used for improved welding results

Table 6.1 Shielding gases for TIG and MIG welding

6.2 Thermoelectric Couples

- Thermoelectric peltier cooler or generator TEC1-12706
- Create a temperature differential on each side
- One side gets hot and the other side gets cool
- Designed for cooling and heating up to 90 degree Celsius applications

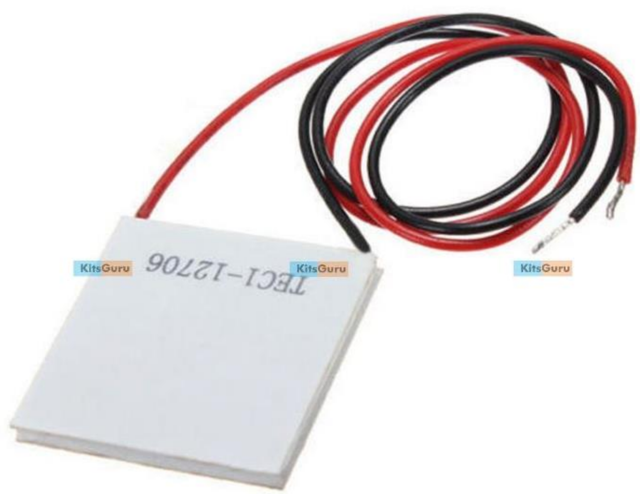


Figure 6.1 Thermoelectric Couple

Specifications for this item	
Brand Name	Generic
Ean	6329161934776
Item Weight	18 grams
Manufacturer Series Number	KG103
Part Number	KG103

Table 6.2 Specifications of Thermoelectric couple

6.3 Series and Parallel Connection of Thermoelectric Couple

- Series:
  Thermocouples connected in series produce an EMF signal that is additive. That is the output from a number of thermocouples are added together to produce a total output of all the thermocouples. With reference to figure 6.1, the formula for working this out is:

$$E = ET_1 + ET_2 + ET_3 + ET_4$$

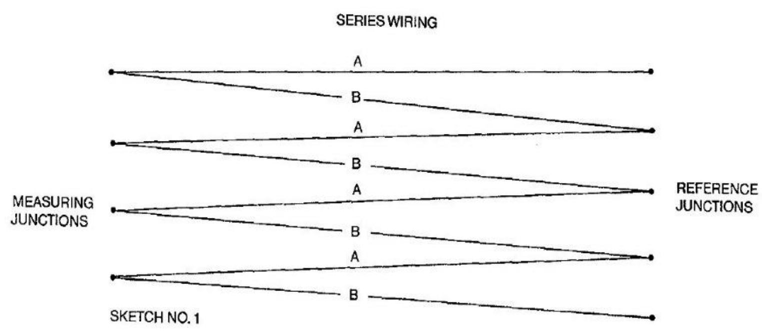


Figure 6.2 Series Connection of Thermocouples

- Parallel:
  Thermocouples connected in parallel produce an EMF signal same as for a single thermocouple. If all thermocouples are of equal resistance and their measuring junctions are at various temperature, then the EMF generated will correspond to the average of the temperatures of the individual junctions. The formula applies is:

$$EMF = \frac{T_2+T_3+T_4+T_5}{4}$$

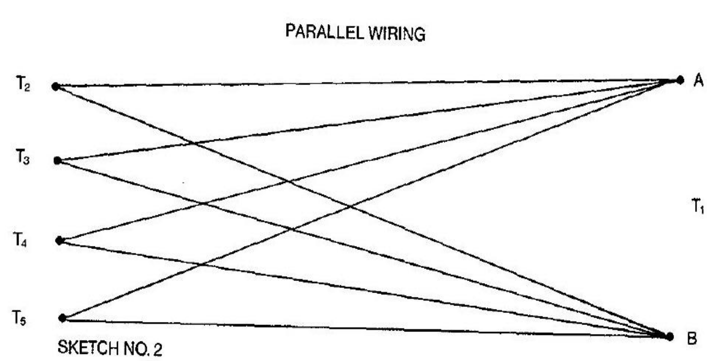


Figure 6.3 Parallel Connection of Thermocouples

6.4 Other Component

- CPU Fan:

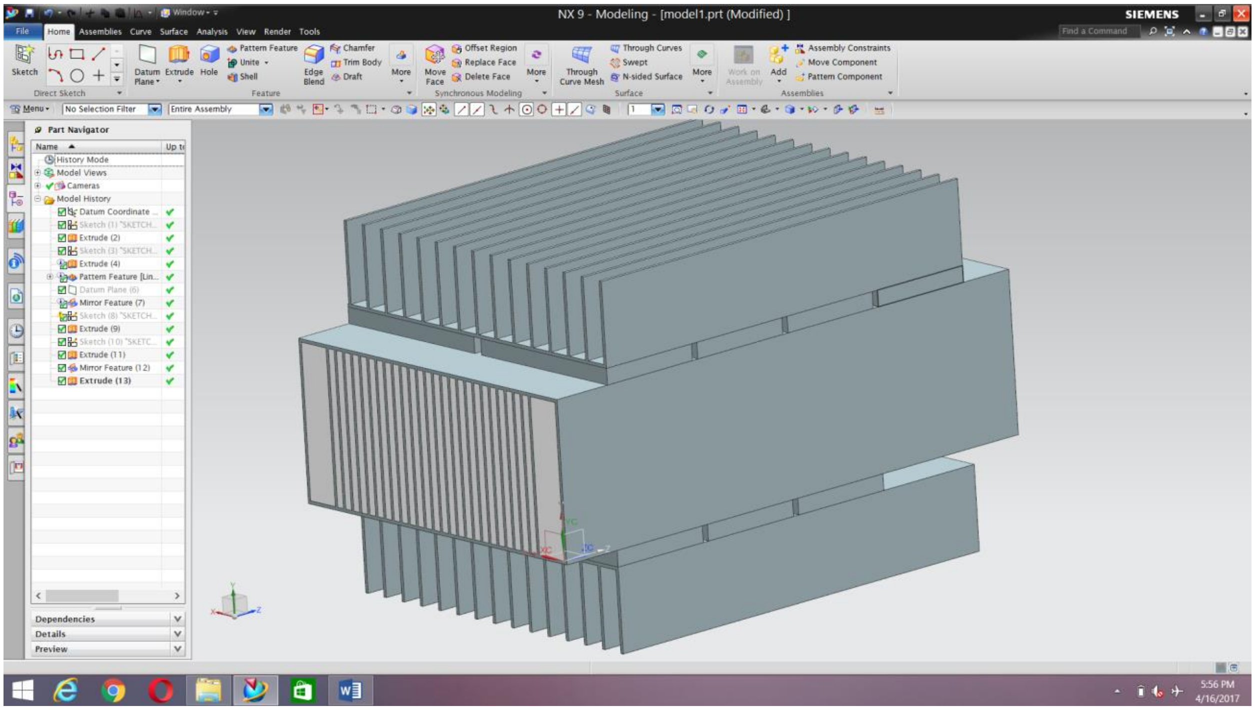
Brand	MAA KU
Model	9225
Product Dimensions	9.2*2.5*9.2cm
Voltage	12 Volts
Wattage	2.4 Watts
Power Source	DC

Table 6.3 Specifications of Fan

Figure 6.4 CPU Fan

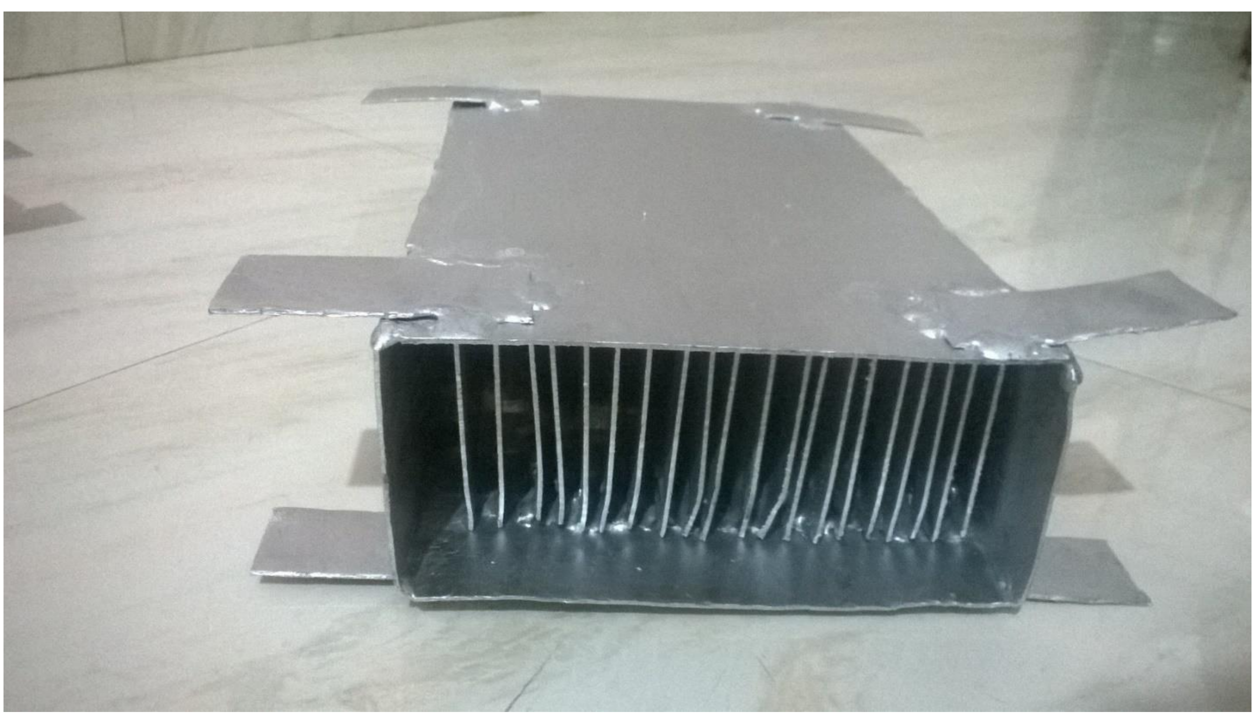
6.5 Final Model

- NX Design Model



- Experimental Model

1. Duct



2. Heat Sink

CHAPTER-7

CONCLUSION

A Thermoelectric Air cooling for car prototype was designed and built which can be used for personal cooling inside the car. Fifteen TECs were used for achieving the cooling with a DC power supply through car battery. It had been shown from testing results that the cooling system is capable of cooling the air when recirculating the air inside the car with the help of blower. TEC cooling designed was able to cool an ambient air temperature from 42.5°C to 31°C. Cooling stabilizes within few minutes once the blower is turned ON. The system can attain a temperature difference of set target which was 11.5°C. Accomplishing the set target establish the success of the project. So on the basis of theoretical calculation the cooling can be done successfully with the help of thermoelectric couple.

GENERAL TERMS

Symbol	Description / Units
Q_{met}	Metabolic Load W/m^2
Q_{Dir}	Radiation Load W/m^2
S	Surface area
$\dot{Z}_{Dir}$	Direct radiation heat gain per unit area W/m^2
θ	Angle between surface element & position of sun in sky
β	Altitude angle
α	Glass solar azimuth angle
θ_{inc}	Inclination angle
I_{Dir}	Direct radiation
Q_{Dif}	Diffuse Load W/m^2
ξ	Tilt angle of surface
Q_{Ref}	Reflected radiation W/m^2
Q_{Amb}	Ambient Load W/m^2
T_s	Average surface temperature K
T_i	Average cabin temperature K
h_i	Outside thermal conditions
h_o	Inside thermal conditions
k	Surface thermal conductivity
λ	Thickness of surface element m
v	Velocity of vehicle m/s
Q_{Exh}	Exhaust Load W/m^2
S_{Exh}	The area of the bottom surface in contact with the exhaust pipe m^2
Q_{Eng}	Engine Load W/m^2
$Q_{ventilation}$	Ventilation Load W/m^2
Q_{total}	Total Load W/m^2
Q_{AC}	AC Load W/m^2
I	Current A
α	Differential Seebeck coefficient
T_H	Hot side thermocouple temperatures K
T_C	Cold side thermocouple temperatures K
Q_C	Cooling effect W
Q_h	Heating effect W
T_{Eng}	The engine temperature K

KEYWORDS

TEM -thermoelectric modules
TEC -thermoelectric couple
CFC - Chloro fluro carbon

REFERENCES

- Refrigeration & air conditioning by the author R. S. Khurmi
- Performance Evaluation of a Thermoelectric Refrigerator (www.ijeit.com)
- Thermoelectric Cooling Modules (a report by G Gromov RMT Ltd.)
- HVAC (Heat Ventilation and Air Conditioning System) Using TEC (Thermoelectric Couple) (http://www.iosrjournals.org)
- Thermoelectric Air Cooling For Cars (By Manoj S. Raut Nagpur, India)