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DESIGN AND THERMAL ANALYSIS OF THERMO-ELECTRIC REFRIGERATOR

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ABSTRACT

In this project we are using solar panels for charging a Lead Acid Battery (12V, 1.2 Amp hrs.), a pelteir thermoelectric device when connected to battery generates cool effect and hot effects depending on the mode required by the user. Since we are using this for fridge, we need only cool mode. A peltier thermoelectric device is connected to the battery to generate cooling effect. We need to display the voltage for that we are using ADC0808 which is given to the controller. For this ADC we are giving a clock pulse through 555 timers to perform its operation. The aim of the project is to design a compressor less refrigerator system and A parametric model of the refrigerator is designed using 3D modeling software CATIA. Catia is the standard in 3D product design, featuring industry-leading productivity tools that promote best practices in design.

1.0 INTRODUCTION

Evaporative cooling in refrigeration is an old idea but due to its dependency on outside environment (relative humidity, dry bulb temperature) it is limited to certain parts of world. Some of the examples for evaporative cooling are clay pots used in India for cooling the drinking water. In Mexico, fishermen use freezer to produce ice for storing fish. In Australia, Cool grade safe are used for refrigeration purpose. In this project we have tried to minimize the effect of outside environment. With time many techniques, laws and methods have been discovered by scientists. The See beck and Peltier Effect account to be one of them. When a closed circuit of two dissimilar metals and two junctions is formed, a current will flow between the junctions or the circuit. This phenomenon is known as the See beck effect. The effect takes place when the temperature between the junctions shows difference. The greater the temperature difference, the more will be the electric current between the junctions. This is the fundamental principle used in the thermocouple. The combinations of metals or semiconductors affect the flow of current. This effect is used in thermal analysis and also for heat flow compensation. With time many researches were conducted, many new theories and with them many new devices were put forth. Air Conditioner, Refrigerator etc. are few of them, where by the use of electricity, cooling is obtained. But in these devices cooling does not just takes place totally due to electricity (here for efficiency and fast rate of cooling Refrigerants), compressors are used.

Fig 1.1: Evaporative cooling in refrigeration

Vapor-compression refrigeration or vapor-compression refrigeration system (VCRS), in which the refrigerant undergoes phase changes, is one of the many refrigeration cycles and is the most widely used method for air-conditioning of buildings and automobiles. It is also used in domestic and commercial refrigerators, large-scale warehouses for chilled or frozen storage of foods and meats, refrigerated trucks and railroad cars, and a host of other commercial an industrial service. Oil refineries, petrochemical and chemical processing plants, and natural gas processing plants are among the many types of industrial plants that often utilize large vapor-compression refrigeration systems.
Refrigeration may be defined as lowering the temperature of an enclosed space by removing heat from that space and transferring it elsewhere. A device that performs this function may also be called an air conditioner, refrigerator, air source heat pump, geothermal heat pump or chiller (heat pump).
The vapor-compression uses a circulating liquid refrigerant as the medium which absorbs and removes heat from the space to be cooled and subsequently rejects that heat elsewhere. Depicts a typical, single-stage vapor-compression system. All such systems have four components: a compressor, a condenser,

a thermal expansion valve (also called a throttle valve or metering device), and an evaporator. Circulating refrigerant enters the compressor in the thermodynamic state known as a saturated vapor and is compressed to a higher pressure, resulting in a higher temperature as well.
The basic principles are those of physics and thermodynamics, and these principles apply to all applications. One of the most famous applications of refrigeration is the protection of perishable food products by storing them at low temperatures. Refrigeration systems are also widely used to provide thermal comfort to humans through air conditioning. Overview Air conditioning refers to the treatment of air in order to control its temperature, moisture content, cleanliness, odor, and circulation, as required by the occupants of the space, a process, or products simultaneously. The name of refrigeration and air conditioning evolved from the human need for food and comfort and has a centuries-old history. The history of refrigeration is very interesting as its aspects, availability of refrigeration, developments in prime movers and compressors, and the method of refrigeration are part of it.

1.1 How Refrigeration Works?

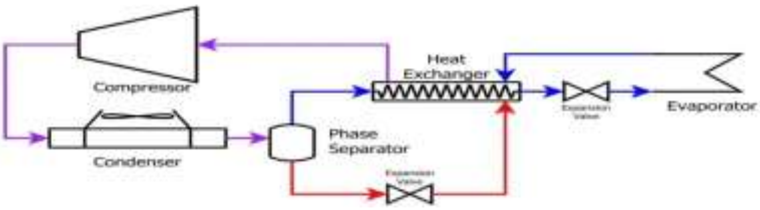

Fig 1.2 Vapor compression refrigeration

Following are the types of refrigeration are explained below:

- Mechanical compression refrigeration
- Evaporative cooling
- Absorption refrigeration
- Thermoelectric refrigeration
- Vapor compression refrigeration
- Vapor absorption refrigeration

1.1 Mechanical Compression Refrigeration
Mechanical compression refrigeration systems are commonly used for commercial and industrial refrigeration as well as air conditioning. In these types of refrigeration systems, the refrigerant vapor is compressed by means of a centrifugal, screw, or reciprocating compressor.
Mechanical refrigeration systems have high power consumption for the compressor and pumps needed for the cooling water circuit. After compression, the vapor passes to a condenser where it condenses, this vapor is then expanded in an expansion valve and gives a cooling effect.

1.3 Absorption Refrigeration

Absorption refrigeration is a system that uses a heat source (which may be solar power or a fossil-fueled flame) to provide the energy needed to run the cooling process. It uses two types of coolant, the first coolant performs evaporative cooling and is then absorbed into the second coolant.
Now, heat is required to reset the two coolants to their primary state. This principle also is used to air-condition buildings using waste heat from gas turbines or water heaters. Absorption refrigeration systems are commonly used in recreational vehicles, campers, and caravans.

1.4 Thermoelectric Refrigeration

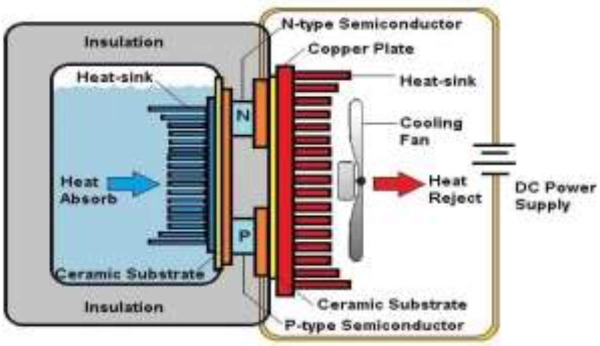

Figure 1.3 Thermoelectric Refrigeration

The thermoelectric refrigeration system normally works on the principle of the Peltier effect. This effect makes a variation in temperature by transferring heat between the two conductor junctions. A voltage is applied between the connected conductors to produce an electric current.
When current passes through the junctions of two conductors, heat is eliminated at one junction and cooling occurs. Now, heat is collected at the second junction. However, practically the main application of the Peltier effect is cooling. It can also be used as a temperature controller which can be either hot or cold.

1.5 Vapor Refrigeration

The working agents employed n these types are vapors like ammonia, carbon dioxide, sulfur dioxide, Freon's, etc. The vapor refrigeration's can be further classified as:

- Vapor compression refrigeration's
- Vapor absorption refrigeration's

2.0 LITERATURE REVIEW

[1] **Anil Kumar, Srivastava, Arun Kumar ,Aaditya Sharma** - The objective of this study is to design and develop a working thermoelectric refrigerator with an interior cooling volume of 5 litres that utilizes the Peltier effect to refrigerate and maintain a selected temperature from 5 °C to 25 °C. The design requirements are to cool this volume to required temperature within a time period of 6 hrs and provide retention for at least next half an hour.

[2] **Elavarasan E, Saravanan S, Abhishek Kumar, Anaitullah, Ashok Sah, Karan Kumar** - The objectives of this study is to develop a working thermoelectric refrigerator to cool a volume of 40 L that utilizes the Peltier effect to cool and maintain a selected temperature range of 3 0C to 23 0C. The design requirements are to cool this volume to temperature within a short time and provide retention of at
[3] **Zaloa Azkorra-Larrinaga, César Escudero and Josu Soriano** '' Experimental Study of Mini Thermoelectric Refrigeration'' This paper studies a refrigeration system by using thermoelectric effect (peltier), a module for controlling the temperature within an enclosed structure that is provided in the system. It consists of controller system, transducers, cooling fan and sensing element. The desired temperature which was about 5°C for 10 litres of loads as similar as normal refrigerators, the various parameters of this module are of cooling fan voltage (CFV), Peltier Voltage (PV) and ambient temperature (Ta). The results show that the COP was increasing from 0.14 to 0.47 with the gradual decrease of temperature in the cooling region from 303 K to 284 K. The thermoelectric effect of refrigerator increased with a higher amount of heat rejected from the heat sink.
[4] **Sreejith, K.T.R. Sreesastha Ram, Antony Babu, Anvar A.Y.Calwin, J. Kundukulam, Deepak Charles.** ''Experimental Investigation of Mini Cooler cum Freezer '' In general cases the refrigerator could be converted into an air conditioner by attaching a fan. Thus a cooler as well as freezer is obtained in a single set up. The freezer can be converted to an air conditioner when the outside air is allowed to flow beside the cooling coil and is forced outside by an exhaust fan. In thiscase a mini scale cooler cum freezer using R134a as refrigerant was fabricated and tested. In our mini project work we had designed, fabricated and experimentally analysed a mini cooler cum freezer. From the observations and calculations, the results of mini cooler cum freezer are obtained and are compared
[4] Ane Goenaga, Koldobika Martin-Escudero, Iván Flores-A a research of the current technology was carried out in order to obtain indicative values on the scales that were being worked on and their application. After the previous research, a refrigeration cycle was designed in EES (engineering equation solver). From this design, different conclusions were obtained: (1) The correct sizing of the compressor revolutions together with its displacement is crucial for the equipment to be able to provide the desired cooling capacity. (2) In order to obtain the desired cooling capacity in the microscale refrigeration system, the heat exchangers must have fins. (3) Of the analysed refrigerants, R600a is the best choice, as it shows favourable characteristics (high COP and low compression ratio)

3.0 DESIGN AND ANALYSIS SOFTWARES

3.1 Introduction to CATIA

CATIA (Computer Aided Three-dimensional Interactive Application) is a multi-platform CAD/CAM/CAE commercial software suite developed by the French company Dassault Systems. Written in the C++ programming language, CATIA is the cornerstone of the Dassault Systems product lifecycle management software suite. CATIA competes in the high-end CAD/CAM/CAE market with Cero Elements/Pro and NX (Unigraphics).The 3D CAD system CATIA V5 was introduced in 1999 by Dassault Systems. Replacing CATIA V4, it represented a completely new design tool showing fundamental differences to its predecessor. The user interface, now featuring MS Windows layout, allows for the easy integration of common software packages such as MS Office, several graphic programs or SAPR3 products (depending on the IT environment).The concept of CATIA V5 is to digitally include the complete process of product development, comprising the first draft, the Design, the layout and at last the production and the assembly. The workbench Mechanical Design is to be addressed in the Context of this CAE training course.

CATIA can be applied to a wide variety of industries, from aerospace and defense, automotive, and industrial equipment, to high tech, shipbuilding, consumer goods, plant design, consumer packaged goods, life sciences, architecture and construction, process power and petroleum, and services. CATIA V4, CATIA V5, Pro/ENGINEER, NX (formerly Unigraphics), and Solid Works are the dominant systems.

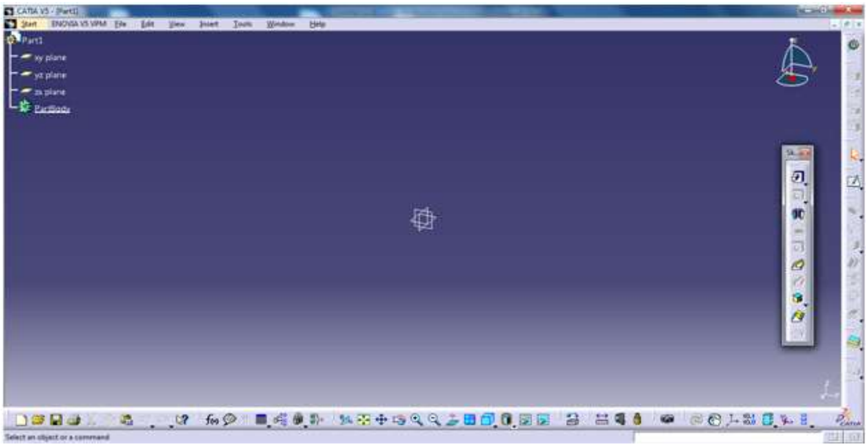

Fig: 3.1: Home Page of CatiaV5

4.0 DESIGN AND ANALYSIS

Modeling of Compressor Less Refrigerator System in CATIA V5

This Compressor Less Refrigerator System is designed using CATIA V5 software. This software used in automobile, aerospace, consumer goods, heavy engineering etc. it is very powerful software for designing complicated 3d models, applications of CATIA Version 5 like part design, assembly design.

The same CATIA V5 R20 3d model and 2d drawing model is shown below for reference. Dimensions are taken from. The design of 3d model is done in CATIA V5 software, and then to do test we are using below mentioned software's.

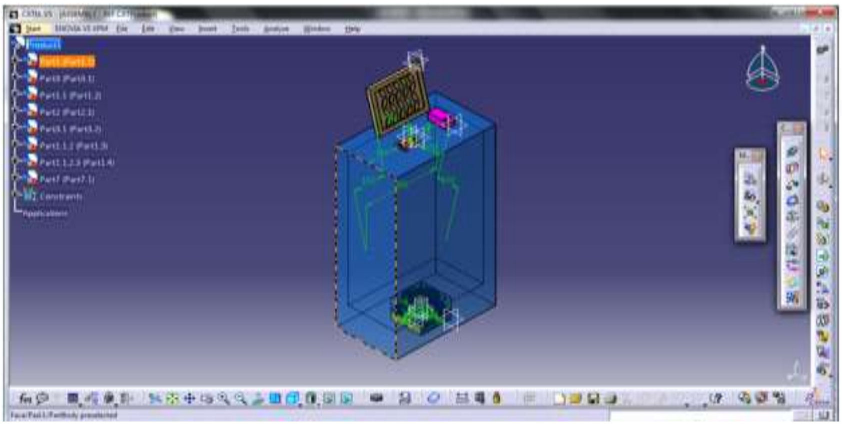

Figure 4.1: Model design in CATIA-V5

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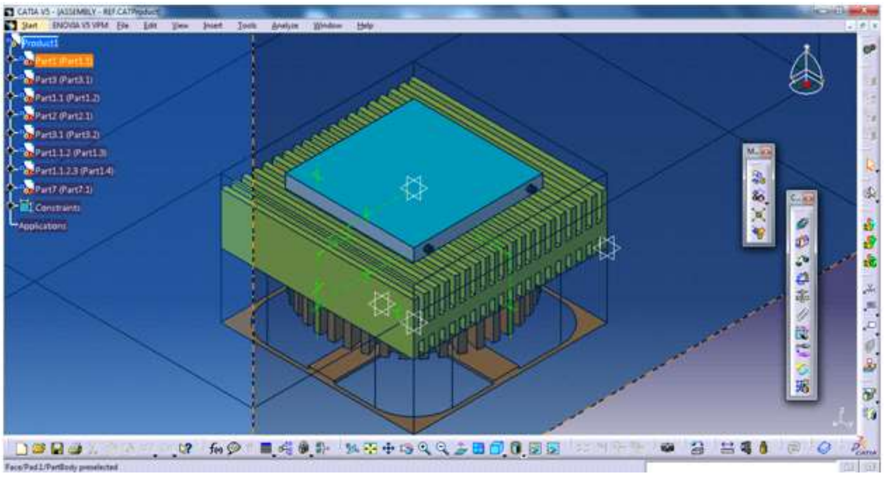

Fig: 4.1.1: Model arrangement of mechanism in CATIA-V5

Design Procedure of Compressor Less Refrigerator System

The Compressor Less Refrigerator System is designed in the Catia V5 software by both the part modeling and Assembly modeling. This modeling is being done by following steps:

Part Modeling of Compressor less Refrigerator System

5.0. DISCUSSION ON ANALYSYS RESULT

5.1 Results of Nodal Temperature:

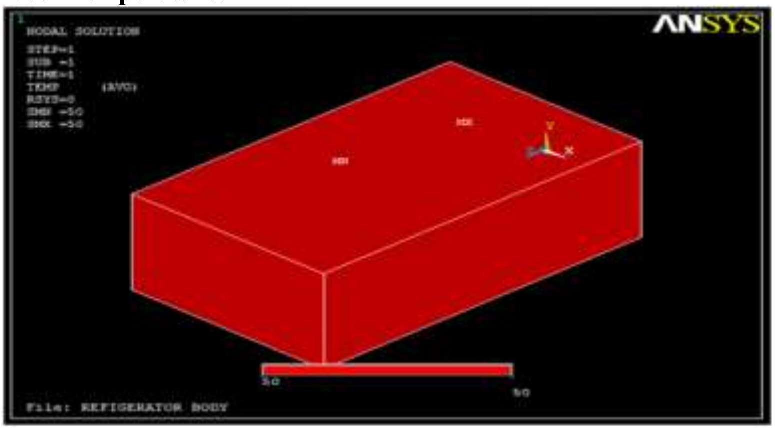

Fig: 5.1: Nodal Temperature of Refrigerator Body

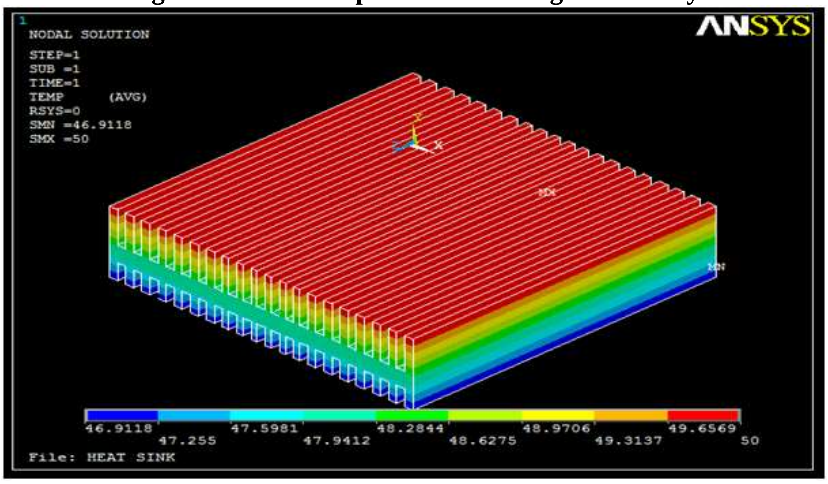

Fig: 5.2: Nodal Temperature of Heat Sink

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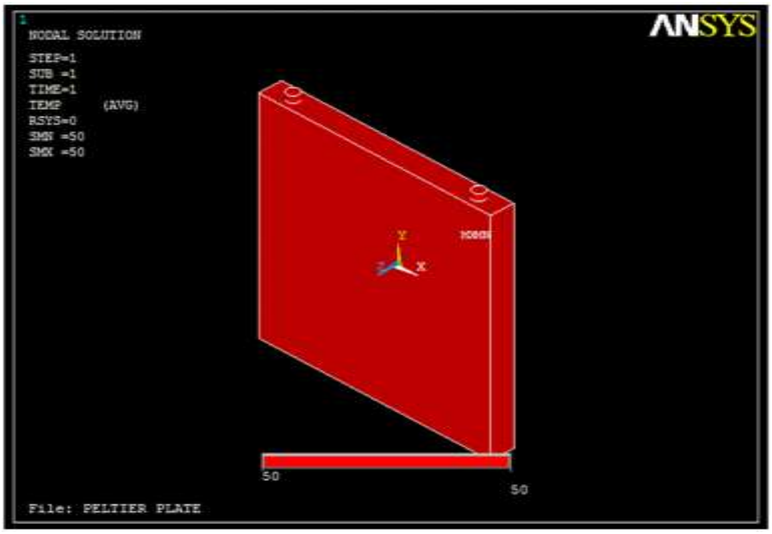

Fig: 5.3: Nodal Temperature of Peltier Plate

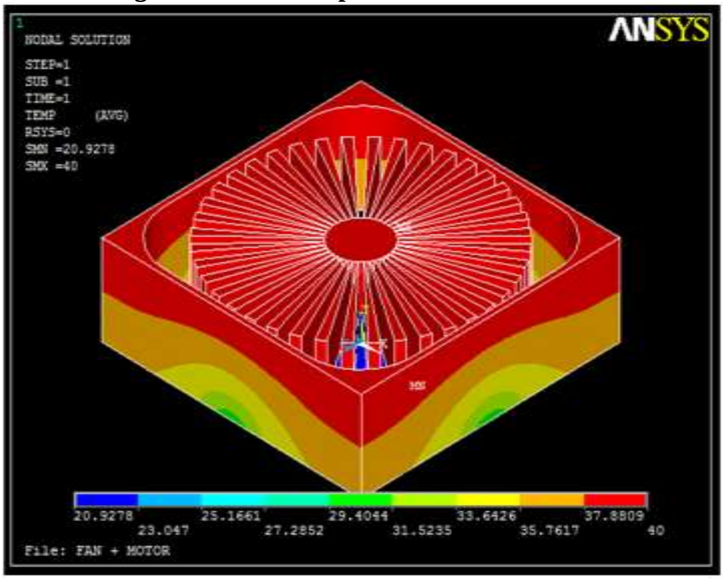

Fig: 5.4: Nodal Temperature of Fan + Motor

Nodal Temperature of the complete design is meshed and solved using Ansys and Nodal Temperature for Refrigerator Body is 50, for Heat Sink is 46.9, for Peltier Plate is 50 and for Fan + Motor is 20.9. This is showing us that clearly each component in assembly is having good output.

5.1.2 Results of Thermal Gradient:

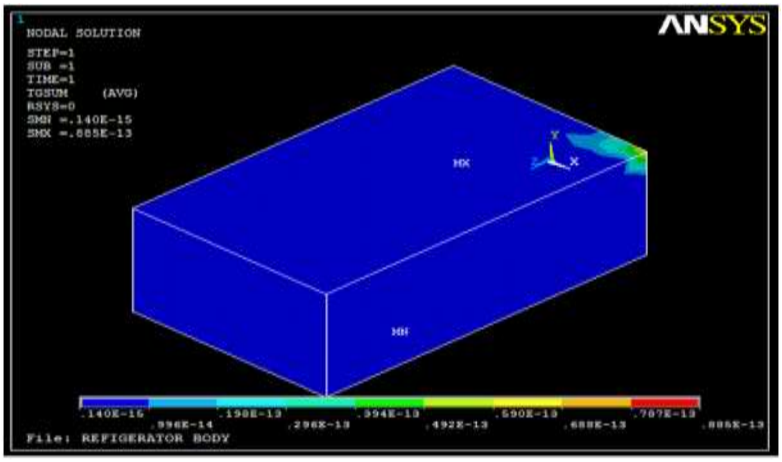

Fig: 5.1.2: Thermal Gradient Analysis of Refrigerator Body

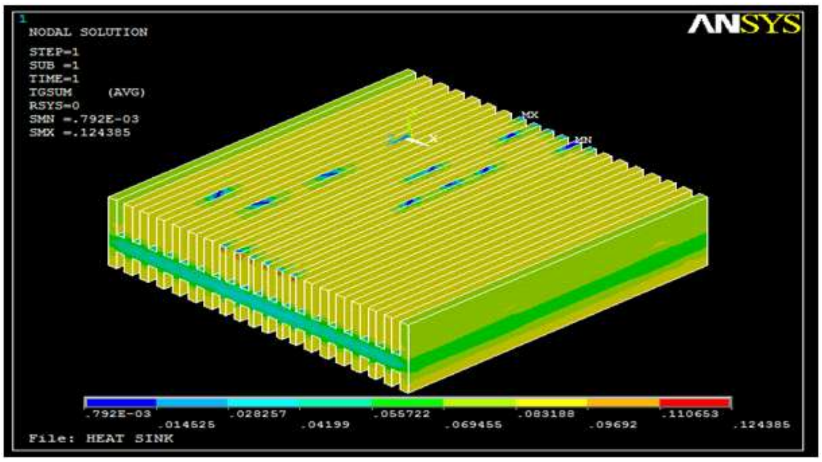

Fig: 5.1.3: Thermal Gradient Analysis of Heat Sink

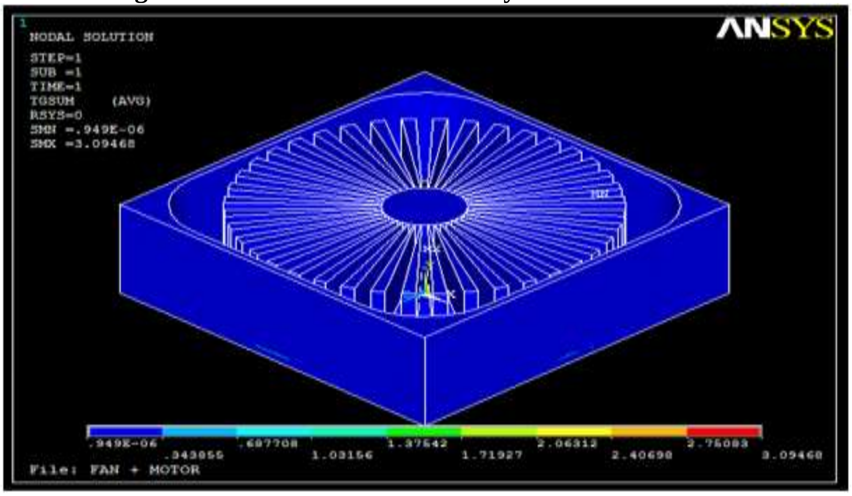

Fig: 5.1.5: Thermal Gradient Analysis of Fan + Motor

The maximum Thermal gradient is coming, this solution solving with the help of Ansys software so that the maximum Thermal gradient for Refrigerator Body is 0.885E-13, for Heat Sink is 0.124, for Peltier Plate is 0.209E-11 and for Fan + Motor is 3.09.

5.1.6 Results of Thermal Flux:

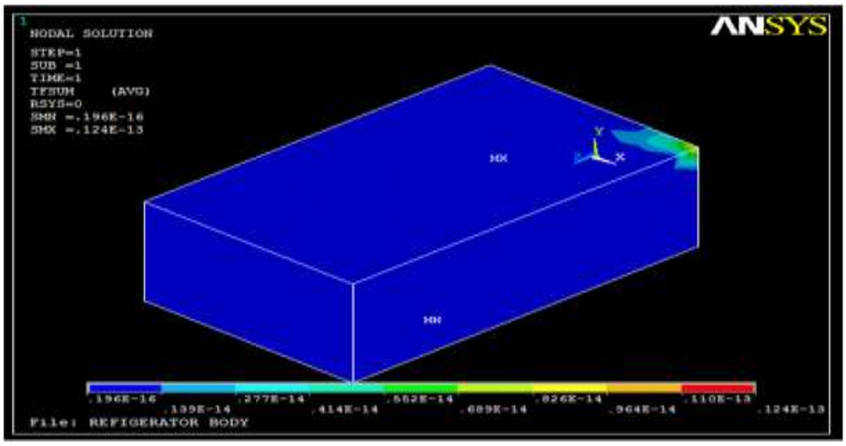

Fig: 5.1.7: Thermal Flux Analysis of Refrigerator Body

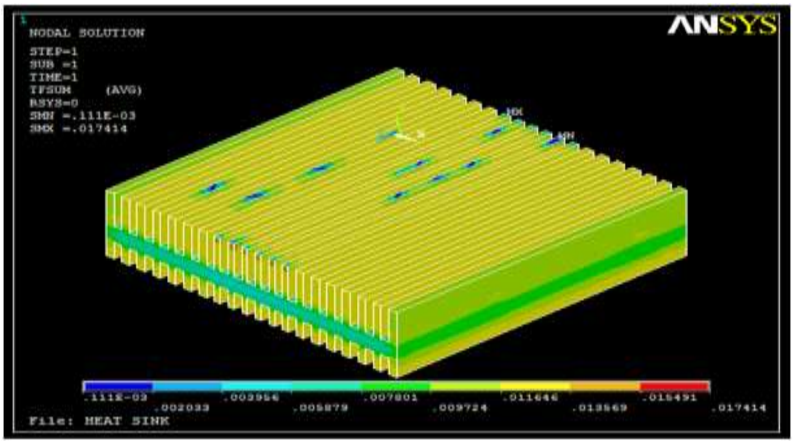

Fig: 5.1.8: Thermal Flux Analysis of Heat Sink

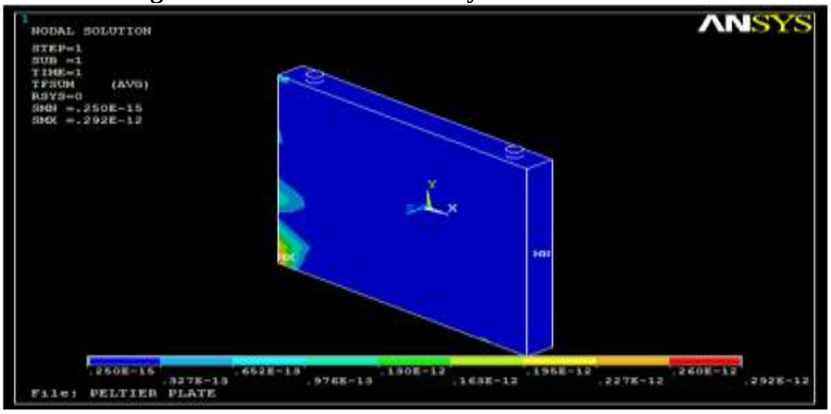

Fig: 5.1.9: Thermal Flux Analysis of Peltier Plate

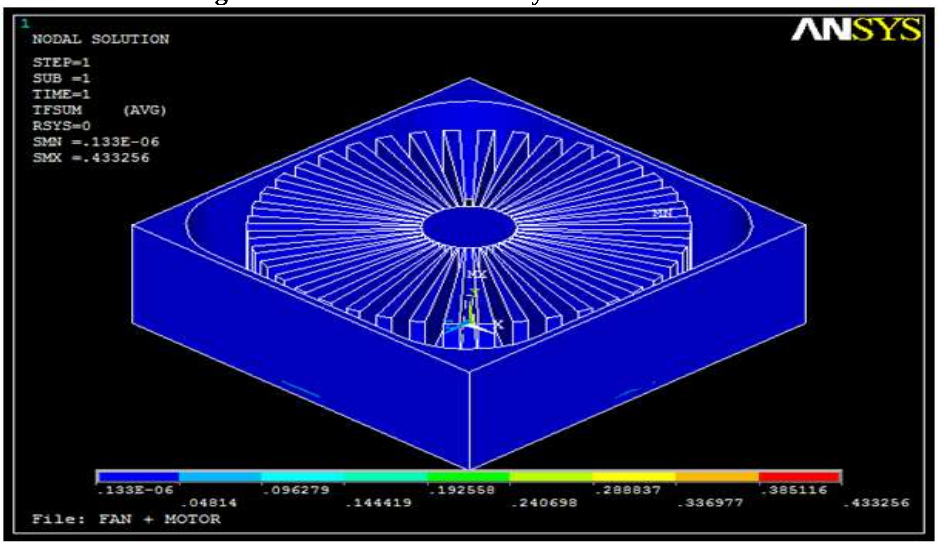

Fig: 5.2.0: Thermal Flux Analysis of Fan + Motor

The maximum Thermal flux is coming, this solution solving with the help of Ansys software so that the maximum Thermal flux for Refrigerator Body is 0.124E-13, for Heat Sink is 0.017, for Peltier Plate is 0.292E-12 and for Fan + Motor is 0.433.

Table 5.1 Comparison of existing and modified refrigerator

S.NO	EXISTING REFRIGERATER	MODIFIED REFRIGERATOR
Nodal Temperature of heat sink	46.9	44
Nodal Temperature of Refrigerator body	50	47.9
Nodal Temperature of peltier plate	50	48.5
Nodal Temperature of fan and Motor	20.9	19.5
Result of thermal gradient of body	0.885E-13	0.789E-9

Thermal gradient analysis of heat sink	0.124	0.118
Thermal gradient of peltire plate	0.209E-11	0.208E-09
Thermal gradient of fan and motor	3.09	3.085
Thermal flux analysis of body	0.124E-13	0.124E14
Thermal flux analysis of heat sink	0.017	0.016
Thermal flux analysis of peltier	0.292E-12	0.292E-11
Thermal flux analysis of fan and motor	0.433	0.428
Heat flow analysis of body	0.630E-13	0.635E-12
Heat flow analysis of heat sink	0.0107	0.0105
Heat flow analysis of peltier plate	0.718E-12	0.718E-13
Heat flow analysis of fan and motor	0.0515	0.0526

CONCLUSION

It can be seen from the above result that, our objective to minimization the temperature in refrigerator using constrained thermodynamic system which has been successful. As shown above figures

- The Nodal Temperature of the complete design is meshed and solved using Ansys and Nodal Temperature for Refrigerator Body is 50, for Heat Sink is 46.9, for Peltier Plate is 50 and for Fan + Motor is 20.9. This is showing us that clearly each component in assembly is having good output.
- The maximum Thermal gradient is coming, this solution solving with the help of Ansys software so that the maximum Thermal gradient for Refrigerator Body is 0.885E-13, for Heat Sink is 0.124, for Peltier Plate is 0.209E-11 and for Fan + Motor is 3.09.
- The maximum Thermal flux is coming, this solution solving with the help of Ansys software so that the maximum Thermal flux for Refrigerator Body is 0.124E-13, for Heat Sink is 0.017, for Peltier Plate is 0.292E-12 and for Fan + Motor is 0.433.

That the maximum Heat flow for Refrigerator Body is 0.630E-13, for Heat Sink is 0.0107, for Peltier Plate is 0.718E-12 and for Fan + Motor is 0.0515. So we can conclude our design parameters are approximately correct.

REFERENCES

1. Khurmi R.S., Gupta J.K., “A Textbook of Refrigeration and Air Conditioning”, S.Chand Publications, pg.no.-38-67, 68-107, 654.
2. Vinod Thombre-Patil, “Thermal Engineering”, Nirali Prakashan, pg. no. -1.34, 1.35.
3. Kumar D.S., Nagraj Chaudhary, Rajput R.K. “Mechanical Measurement and Control”.
4. List of Refrigerants, Wikipedia, and the free encyclopaedia.
5. Tan Y.M., Fan W, ChuaK.M, Shi P.Z, “Fabrication of the Thermoelectric Cooler for device integration,”IEEE Xplore, Electronic Packaging Technology Conference, Proceedings of 7th , vol. 2, EPTC 2005.
6. Goldsmid H.J., International Cryogenics Monograph Series: Thermoelectric Refrigeration, Applications of Thermoelectric Refrigeration. New York, U.S.: Springer-Verlag, 1964.
7. Drebushchak V.A., Journal of Thermal Analysis and Calorimetry: The Peltier Effect. Netherlands: Springer, pp.311-315, Issue 1, vol .91, Jan 2008.
8. Salas V., Olias E,Barrado A, Lazaro A, “Solar Energy Materials & Solar Cells ” Review of maximum power point tracking algorithms for standalone photovoltaic systems .Elsevier B.V. vol. 90, pp.1555-1578, Jul 2006.
9. Desideri V, Proietti S, Sdringola P, Solar –Powered cooling systems: Technical & economic analysis on industrial refrigeration and air-conditioning applications .Elsevier B.V., vol.86, pp.1376-1386, Sep 2009.
10. Taylor, R.A., Solbrekken, G., Comprehensive system-level optimization of thermoelectric devices for electronic cooling applications, Componnents and Packaging Technologies, IEEE Transactions on (Volume:31, Issue: 1)
11. "Thermoelectric Coolers Basics". TEC Microsystems. Retrieved 16 March 2013.