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DESIGN AND ANALYSIS THERMOELECTRIC REFRIGERATOR

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Abstract: In Today's world global warming is being increasing year by year. There are many reasons like pollution, deforestation, water contamination, etc...In coming years the major problem before us is depletion of ozone layer which is caused by the release of CFC's. Some of the equipment which causes this effect is refrigerators, AC's. In this project we are mainly focusing on a solution to control this problem we have focused on refrigerators which releases CFC's. Here we are designing a mini solar based refrigerator which is cheaper as well as eco-friendly. In this project we are using solar panels for charging a Lead Acid Battery (12V, 1.2 Amp hrs), a peltier 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 ADC which is given to the controller. For this ADC we are giving a clock pulses through 555 timers to perform its operation. The aim of the project is to design and analyze a compressor less refrigerator system. A parametric model of the refrigerator is designed using 3D modeling software Catia and analyzes using Ansys Software. Catia is the standard in 3D product design, featuring industry-leading productivity tools that promote best practices in design.

I- 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 gardie 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 Seebeck 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 Seebeck 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. Jean.C.Peltier, a French watchmaker and an amateur scientist discovered a reverse effect of the Seebeck. He discovered that using joined dissimilar metals heat pump can be made. He found that by the use of two dissimilar metals if current is passed between the junctions, the two junctions will create a temperature difference between them. One junction becomes hot and the other becomes cool. This is the basis on which our project works.

The Peltier effect is the heat liberation at one junction of thermocouple and heat absorption at the other, when an electric current flows into it. 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.

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 and industrial services. 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.

II - LITERATURE SURVEY

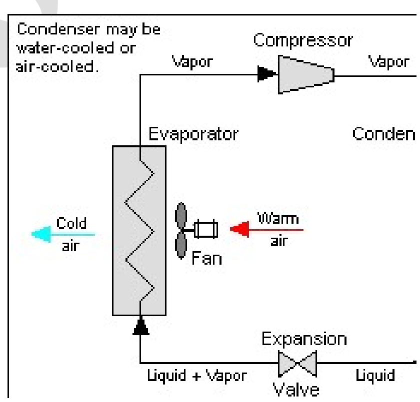
Nevertheless, there still remain two limitations in the current practice of solar absorption refrigeration which have limited its spread. As with all solar technologies, high first cost is a problem. Any measures which would either increase the solar aperture or increase the overall collection efficiency without increasing cost would have the beneficial effect of lowering the first cost per unit of ice produced. Secondly, the inherent functioning of solar intermittent absorption refrigerators is to produce ice at night, which requires evaporator temperatures on the order of - 10 degree C and then use stored ice by day to keep the cold box at slightly above 0.degree. C. In other words, the evaporator region inherently cycles between about -12.degree C. and about +4 degree c, depending on isolation and insulation. Clearly it would be possible to incorporate a separate thermostatic compartment cooled by storage ice which maintains a relatively constant +4.degree C and that would be useful for many refrigeration applications. However, there is another category of applications which require a relatively constant - 20.degree. C. This is the temperature of the frozen food section of most domestic refrigerators, i.e., the “freezer compartment.” Examples of commodities which require this level of refrigeration for long term storage include oral polio vaccine, measles, and yellow fever vaccines. Although conventional intermittent absorption cycles could easily be adjusted to yield -20.degree. C. at night, at some loss in efficiency, they have no practicable mechanism for maintaining that temperature by day. Multiple-staged absorption cycles are well-known in the art, especially for continuous cycles. See for example U.S. Pat. Nos. 4,402,795 and 4,475,361. Some previous work has also been done on intermittent cycles with multiple stages, for example the technical article by A. Mani and A. Venkatesh appearing at p. 271 of Vol. 26 No. 3/4 1986.

Energy Conversion and Management entitled "A Two Stage Intermittent Solar Refrigeration System—Evaluation of Salient Parameters". In that article, a two-stage generator and absorber configuration is disclosed which enables use of much lower heat source temperatures (approximately 70.degree. C.), albeit at much lower Coefficient of Performance.

The capital cost problems relating to aperture size and collection efficiency stem from twoconstraints. First is the sidereal motion. The elevation angle of the sun at solar noon changes by 46.5.degree. Through the course of the year. At three hours either side of solar noon, the change is about 5820. Secondly, the inherent functioning of the intermittent absorption refrigeration cycle requires average temperatures on the order of 50.degree C above ambient and afternoon peak temperatures some 15 degree C higher. The collection efficiency of flat plate collectors is simply too low at those temperatures. It is known that as the collection temperature increases, a concentrating collector (solar aperture larger than solar target) becomes more efficient than a flat plate collector. The decreased loss due to heat leakage from the smaller target offsets the increased loss due to reflections. In the technical article "Low Concentration CPC's for Low Temperature Solar Energy Applications", February 1986, Journal of Solar Energy Engineering, Vol. 108 p. 49, J. M. Gordon shows that a truncated CPC with acceptance half angle of 30.degree. Becomes more efficient than a flat plate collector at 21K above ambient for a concentration ratio (CR) of 1, and at 36K for a CR of 1.5.

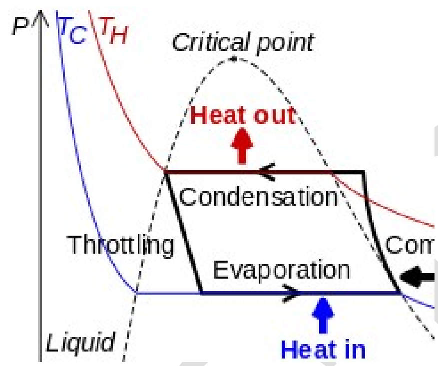
III - DESCRIPTION OF THE PROJECT

The condensed liquid refrigerant, in the thermodynamic state known as a saturated liquid, is next routed through an expansion valve where it undergoes an abrupt reduction in pressure. That pressure reduction results in the adiabatic flash evaporation of a part of the liquid refrigerant. The auto-refrigeration effect of the adiabatic flash evaporation lowers the temperature of the liquid and vapor refrigerant mixture to where it is colder than the temperature of the enclosed space to be refrigerated.



The cold mixture is then routed through the coil or tubes in the evaporator. A fan circulates the warm air in the enclosed space across the coil or tubes carrying the cold refrigerant liquid and vapor mixture. That warm air evaporates the liquid part of the cold refrigerant mixture. At the same time, the circulating air is cooled and thus lowers the temperature of the enclosed space to the desired temperature. The evaporator is where the circulating refrigerant absorbs and removes heat which is subsequently rejected in the condenser and transferred elsewhere by the water or air used in the condenser.

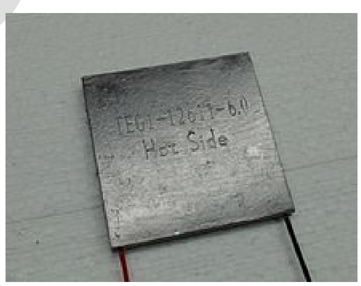
To complete the refrigeration cycle, the refrigerant vapor from the evaporator is again a saturated vapor and is routed back into the compressor.



"Freon" is a trade name for a family of haloalkane refrigerants manufactured by DuPont and other companies. These refrigerants were commonly used due to their superior stability and safety properties: they were not flammable at room temperature and atmospheric pressure, nor obviously toxic as were the fluids they replaced, such as sulfur dioxide. Haloalkanes are also an order(s) of magnitude more expensive than petroleum derived flammable alkenes of similar or better cooling performance.

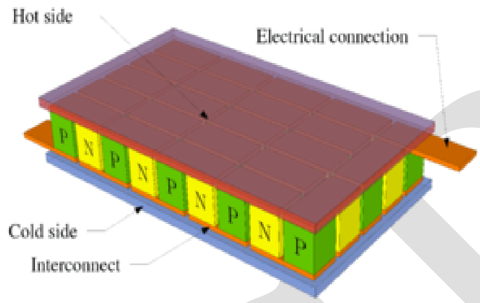
IV - WORKING PRINCIPLE

Thermoelectric cooling uses the Peltier effect to create a heat flux between the junctions of two different types of materials. A Peltier cooler, heater, or thermoelectric heat pump is a solid-state active heat pump which transfers heat from one side of the device to the other, with consumption of electrical energy, depending on the direction of the current. Such an instrument is also called a Peltier device, Peltier heat pump, solid state refrigerator, or thermoelectric cooler (TEC).
It can be used either for heating or for cooling, although in practice the main application is cooling. It can also be used as a temperature controller that either heats or cools.



This technology is far less commonly applied to refrigeration than vapor-compression refrigeration is. The primary advantages of a Peltier cooler compared to a vapor-compression refrigerator are its lack of moving parts or circulating liquid, very long life, invulnerability to leaks, small size, and flexible shape. Its main disadvantages are high cost and poor power efficiency. Many researchers and companies are trying to develop Peltier coolers that are cheap and efficient.

Thermoelectric coolers operate by the Peltier effect (which also goes by the more general name thermoelectric effect). The device has two sides, and when a DC electric current flows through the device, it brings heat from one side to the other, so that one side gets cooler while the other gets hotter. The "hot" side is attached to a heat sink so that it remains at ambient temperature, while the cool side goes below room temperature. In some applications, multiple coolers can be cascaded together for lower temperature.



A single-stage TEC will typically produce a maximal temperature difference of 70 °C between its hot and cold sides. The more heat moved using a TEC, the less efficient it becomes, because the TEC needs to dissipate both the heat being moved and the heat it generates itself from its own power consumption. The amount of heat that can be absorbed is proportional to the current and time. Where P is the Peltier coefficient, I am the current, and t is the time. The Peltier coefficient depends on temperature and the materials the TEC is made of.

Requirements for thermoelectric materials:

- Narrow band-gap semiconductors because of room-temperature operation
- Heavy elements because of their high mobility and low thermal conductivity
- Large unit cell, complex structure
- Highly anisotropic or highly symmetric
- Complex compositions

Bismuth–antimony telluride crystals, grown on a silicon substrate using electrode position Common thermoelectric materials used as semiconductors include bismuth telluride, lead telluride, silicon germanium, and bismuth-antimony alloys. Of this bismuth telluride is the most commonly used? New high-performance materials for thermoelectric cooling are being actively researched.

V - DESIGN METHODOLOGY OF THERMO REFRIGRATOR

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).

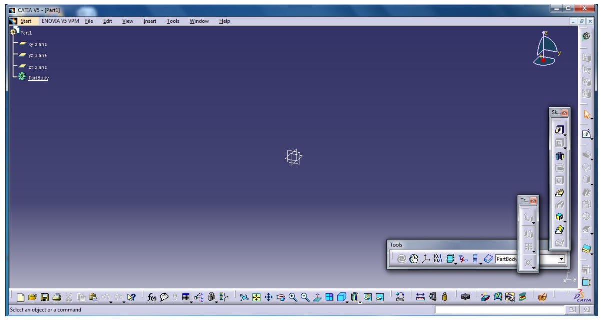


Fig: 5.1: Home Page of CatiaV5

Modeling of Thermo Refrigerator in CATIA V5

This 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.

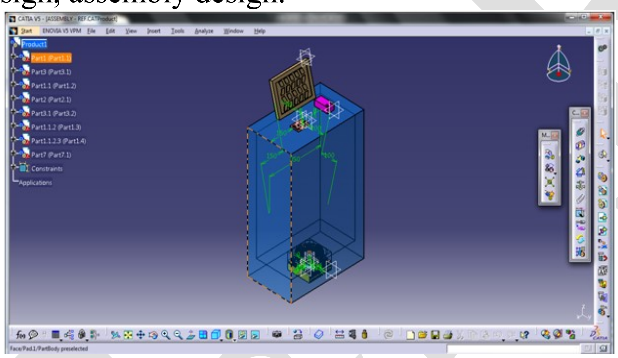


Fig: 5.2: Model design in CATIA-V5

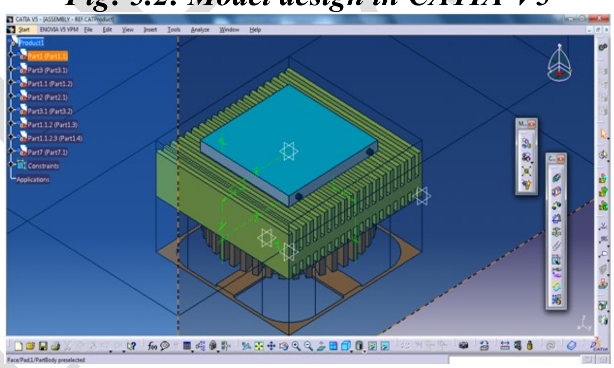


Fig: 5.3: Model arrangement in CATIA-V5

VI - ANALYSIS OF THERMO REFRIGRATOR

6.1 Procedure for FE Analysis Using ANSYS:

The analysis of the refrigerator is done using ANSYS. For compete assembly is not required, is to carried out by applying moments at the rotation location along which axis we need to mention. Fixing location is bottom legs of rod assembly machine.

6.2 Preprocessor

In this stage the following steps were executed:

- **Import file in ANSYS window**

File Menu > Import> STEP > Click ok for the popped up dialog box > Click Browse" and choose the file saved from CATIAV5R20 > Click ok to import the file

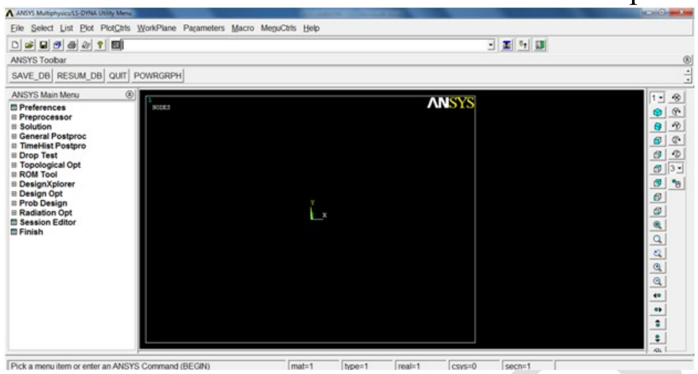


Fig.6.1: Import panel in Ansys.

Rod is modeled with 1d element and shown as above and assembled with adjacent components. Few components are solved using Thermal Analysis for checking the stress and displacements while flowing the fluid.

After completing the meshing of each assembly components next is to do analysis based on the OEM (Original Equipment of Manufacturer) application. So all the models which are analyzed, we need to mention in the Ansys software to get accurate results as per the original component. Some of the components are needed to be solved using thermal analysis.

VII - DISCUSSION ON ANALYSYS RESULT

7.1 Results of Thermal Gradient:

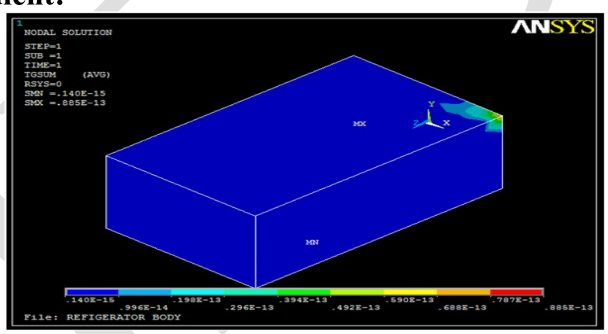


Fig: 7.1: Thermal Gradient Analysis of Refrigerator Body

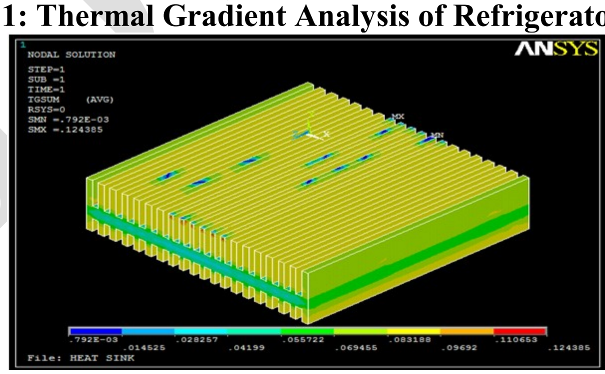


Fig: 7.2: Thermal Gradient Analysis of Heat Sink

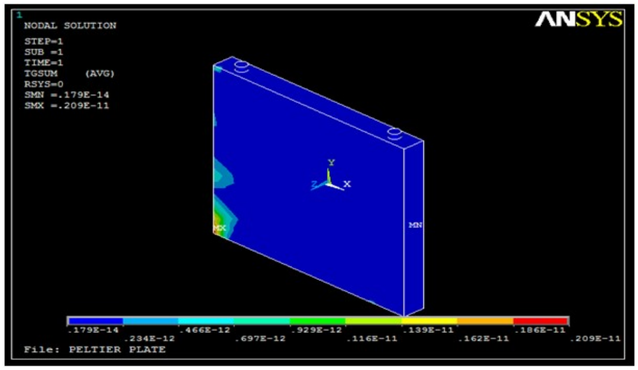


Fig: 7.3: Thermal Gradient Analysis of Peltier Plate

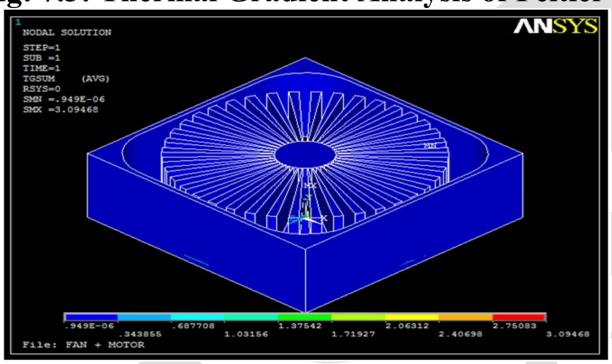


Fig: 7.4: Thermal Gradient Analysis of Fan + Motor

7.3 Results of Thermal Flux:

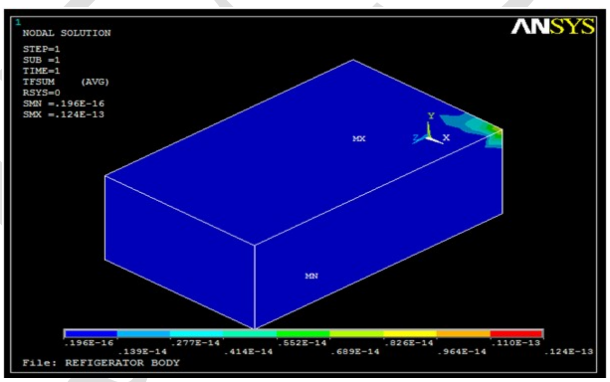


Fig: 7.5: Thermal Flux Analysis of Refrigerator Body

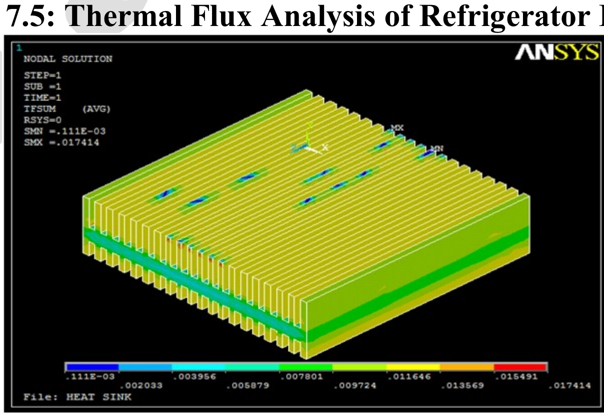


Fig: 7.6: Thermal Flux Analysis of Heat Sink

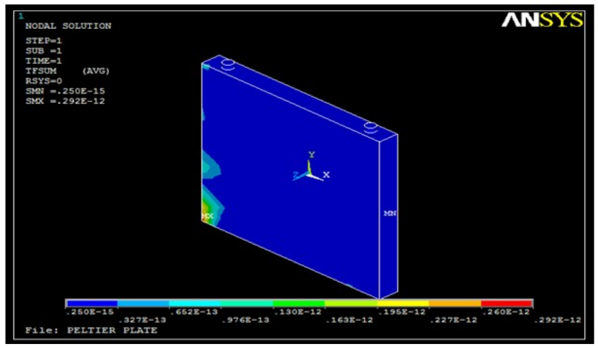


Fig: 7.7: Thermal Flux Analysis of Peltier Plate

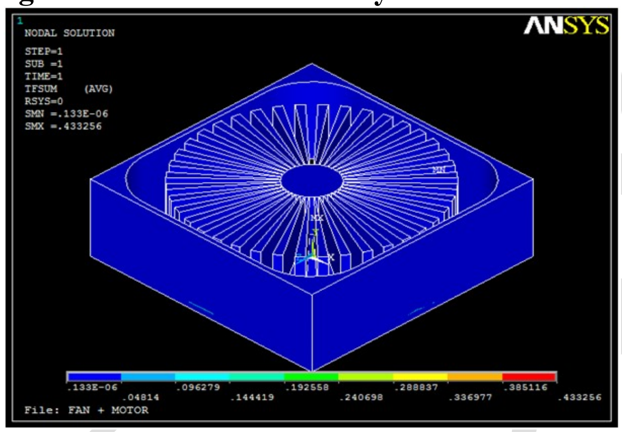


Fig: 7.8: Thermal Flux Analysis of Fan + Motor

7.3 Results of Heat Flow:

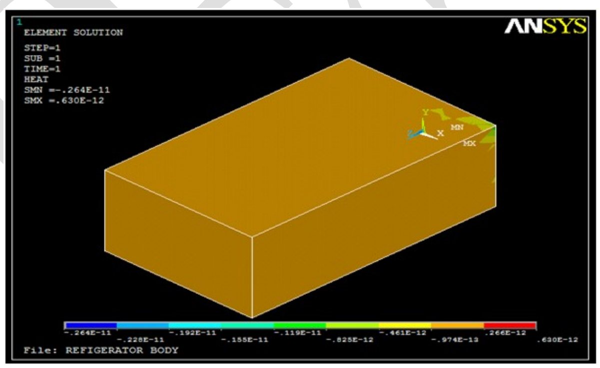


Fig: 7.9: Heat Flow Analysis of Refrigerator Body

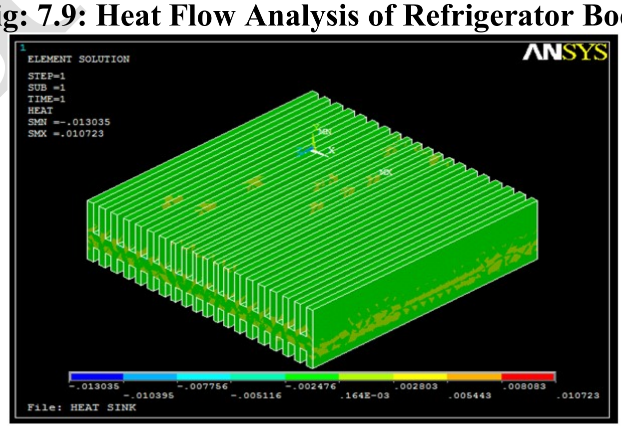


Fig: 7.10: Heat Flow Analysis of Heat Sink

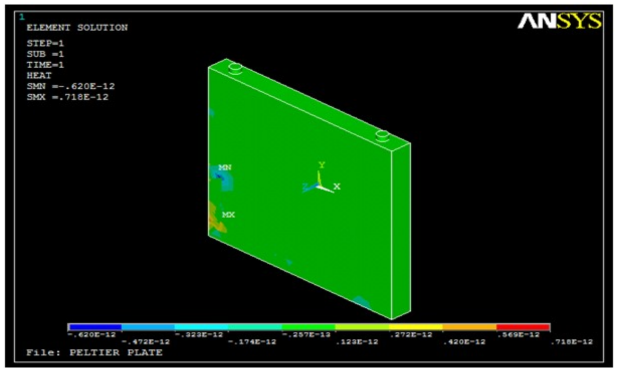


Fig: 7.11: Heat Flow Analysis of Peltier Plate

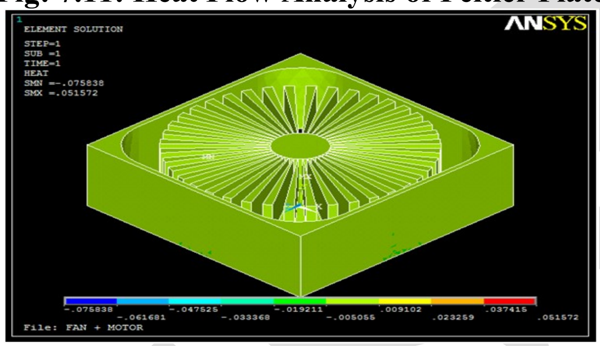


Fig: 7.12: Heat Flow Analysis of Fan + Motor

VIII - 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.

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.

Hence, it can be used only in places where strong sun rays are available throughout the year and most parts of the day.

A highly nonlinear model for the behavior of the compressor less refrigerator is considered. A parametric study to investigate the influence of the control parameters on the response is conducted.

The final result positive manner .There is no problem while in Final assembly design; without failure. For proving that above design is carried out for applying for future works.

The design of the Refrigerator mechanism worked flawlessly in analysis as well, all these facts point to the completion of our objective in high esteem. Finally, I report that original assembly is fine and design model results are shown without any failure.

FUTURE SCOPE

Solar power nowadays is playing a major role in meeting the energy requirements of our country. It is being developed at a very fast rate and its applications in many areas are being explored. The fridge is intended at exploring the same and provides an efficient and economical solution to the areas where there is no electricity and cooling is required.

This project main objective was to develop a mini compressor less solar fridge and this has been successfully done. The applications of this fridge are very wide and it can be used in various places for variety of operations. Also the main purpose for which this fridge is made is being fulfilled as the space inside the fridge is sufficient enough to cool appropriate amount of medicines and injections needed at the primary health care centre's in the villages where there is sporadic or no power supply. Though this fridge is working satisfactorily to its full capacity, still many changes and improvements can be done in this fridge to make it more users friendly and sophisticated in nature.

Number of peltier units can be increased to further decrease the temperature inside the fridge. Same fridge can be used for heating purpose if we also insulate the other side i.e. heating side of the fridge within the box. To increase the volume of the fridge maintaining the same temperature inside the fridge, number of peltier units and heat sink has to be increased. Controllers can be used for making it a temperature controlled fridge. This fridge can also be equipped with a LCD display and digital temperature sensor so that the temperature inside the fridge cans be monitored. In this project, this fridge is made up of Thermo coil and aluminum foils. Wooden material can be used to make this fridge mores sturdy in constructions. Wood will also act as an additional insulator for the cooling compartment.

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