Design and Feasibility Analysis of Peltier Air Cooling System: Design Parameters

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ABSTRACT:- In this paper aims towards testing a sustainable air-cooling system which will produce cooling effect without the use of mechanical devices and also refrigerant. Thermoelectric cooling system does not require working fluids or any moving parts. Thermoelectric cooling devices have a distinct place in medical applications, electronic applications, scientific equipment and other applications. The difference between the existing methods and this model is that a thermoelectric air-cooling system without use of mechanical devices (Conventional Condenser fins and Compressor) and without refrigerant. Testing an efficient model of Peltier air conditioning system is a one step towards it. This project experimentally focuses on testing the Peltier air cooler and then increasing its coefficient of performance (COP) by modifying its efficiency by amending materials. Also testing the various effects of materials on various thermodynamic properties like Air flow rate, Incoming air temperature, Outgoing air temperature, etc. will be investigated.

I.INTRODUCTION

Various researchers are working in this sector as developing such novel cooling system will not only be helpful in saving electricity but also it will be a environment friendly. Thermoelectric cooling has inevitable advantages as compared to compression air cooling system. This project focuses on design analysis of the system and during this all the attention is on increasing the COP of thermoelectric coolers at the same time increasing the effectiveness of thermoelectric module (TEM) is the aim. This can be done in two ways either by amending the materials by which the n/p thermoelectric coolers are made. And by altering the various thermodynamic conditions.

Researchers have done research on thermoelectric modules but the investigation was done on power generation via thermoelectric and a smaller percentage has focused on cooling /heating production using thermoelectric module. Main focus of this project is on cooling application of thermoelectric instead of power generation.

Thermoelectric coolers were made previously but there application was limited only up to the automobile air conditioning system, Air conditioning system for submarines, thermoelectric air coolers for production of cold air and warm water, etc. But commercialisation of this idea is not done yet due to lower values of its COP.

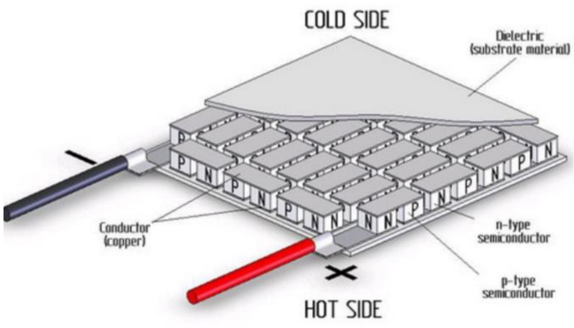
II. EXPERIMENTAL SETUP

The components of the Peltier Air Cooling System will be discussed. There are different components used, the major components of the system are:-

- Closed Cell PVC Foamboard Body
- Peltier Modules
- Hitlon Sheet
- Copper Coils
- Heat Sink (Fins)
- Blowers (Fans)

2.1 Basic Mechanism

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.

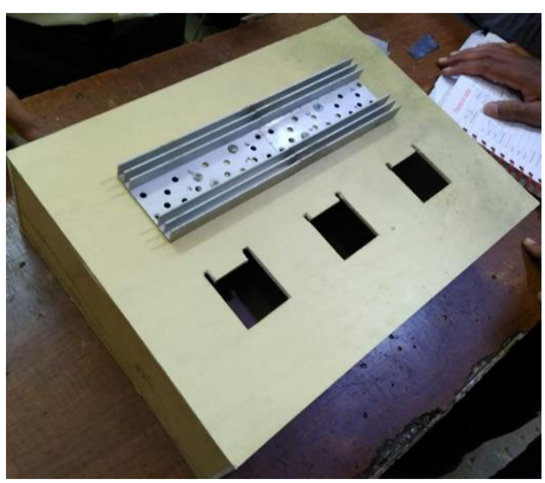


2.2 Main Components

2.2.1 Closed Cell PVC Foam Board Body

A PVC Foam Body is made so that all the components of the cooling system can be mounted on the body. Closed-cell PVC foam board is a lightweight rigid material used primarily in the manufacture of signs and displays. It is considered robust for outdoor use, being immune to rain and resistant to wind and sunlight. It also has thermoplastic properties, and begins to soften at around 65 °C (149 °F).It has a very low moisture absorption. The mixture of polyvinyl chloride and polyurea has a good bond strength. A universal cross-linked closed-cell PVC that was used in a comparison with three heat-resistant cross-linked had a glass temperature of 83.2 °C.

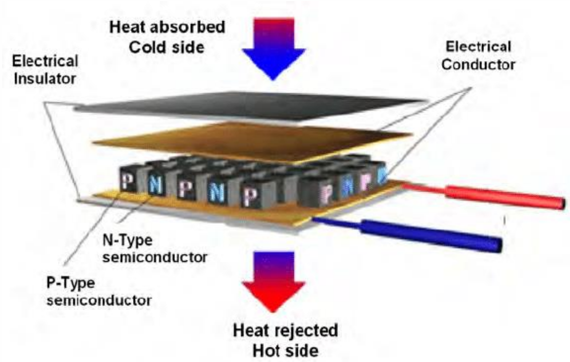
S/No.	Material Properties	Values
1	Density	130 kg/m3
2	Young's Modulus	1.425×10^{8} Pa
3	Poisson's Ratio	0.32
4	Bulk Modulus	1.32×10^{8} Pa
5	Shear Modulus	54 MPa
6	Tensile Ultimate Strength	3.7 MPa
7	Compressive Ultimate Strength	2.8 MPa
8	Isotropic thermal conductivity	0.032 $Wm^{-1}K^{-1}$
9	Specific Heat	1.65 $Jkg^{-1}1C^{-1}$



2.2.2Peltier Modules

Peltier Modules operate according to the Peltier effect. The effect creates a temperature difference by transferring heat between two electrical junctions. A voltage is applied across joined conductors to create an electric current. When the current flows through the junctions of the two conductors, heat is removed at one junction and cooling occurs. Heat is deposited at the other junction.

The main application of the Peltier effect is cooling. However the Peltier effect can also be used for heating or control of temperature. In every case, a DC voltage is required.



2.2.3 **Hitlon Sheet**

EPE foams are low density, semi-rigid, closed cell foam that are generally somewhere in stiffness/compliance between Expanded polystyrene and Polyurethane. Production of EPE foams is similar to that of expanded polystyrene, but starting with PE beads.Typical densities are 29 to 120 kg/m3 (49 to 202 lb/cu yd) with the lower figure being common. Densities as low as 14 kg/m3 (24 lb/cu yd) can be produced.

Base polymer for EPE foams range from Low-density polyethylene (LDPE) to High-density polyethylene (HDPE).

Product Features:

Property	Unit	Value
Density	g/Cm□	0.026-0.045(Depending upon thickness)
Elongation	%	T.D. 40-65
Tensile StrengthAt ambient temp.	Kg/Cm□	M.D.3-7.5T.D. 2.5-3.5
Compression StrengthAt 10 %	Kg/Cm□At 10 %	0.15-0.2
Water absorptionAfter 24 hrs.	Volume	0.02 %
Water Vpour TransmissionRate /24 hrs.	Gm/m□	20-25
Buoyancy (fresh water)	Kg/m□	915
Chemical Ressistance	-	Excellent(similar to LDPE)
Thermal Conductivity	K/cal/M. hr°C	0.025

2.2.4 Heat Sink (Fins)

A **heat sink** a passive heat exchanger that transfers the heat generated by an electronic or a mechanical device. A heat sink is designed to maximize its surface area in contact with the cooling medium surrounding it, such as the air. Air velocity, choice of material, protrusion design and surface treatment are factors that affect the performance of a heat sink. Aluminium heat sinks are used as a low-cost, lightweight alternative to copper heat sinks, and have a lower thermal conductivity than copper.

2.2.5 Blower

A **blower fan** is a mechanical device for moving air or other gases in a outward direction at an angle to the incoming fluid. Blower fans often contain a ducted housing to direct outgoing air in a specific direction or across a heat sink such a fan is also called a **biscuit blower** or **squirrel-cage fan** (because it looks like a hamster wheel). These fans increase the speed and volume of an air stream with the rotating impellers.

Specifications of Blower

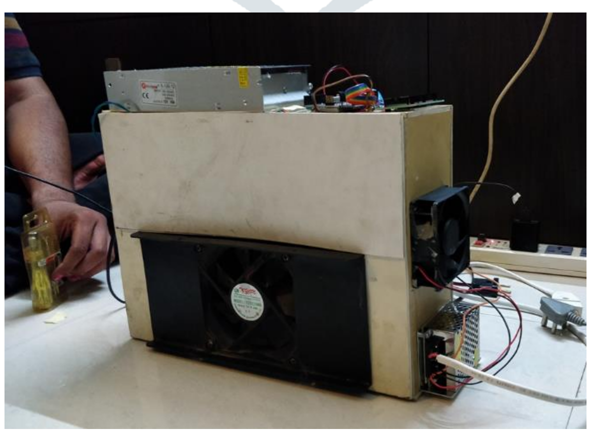
Name of Blower : DC Brushless Fan

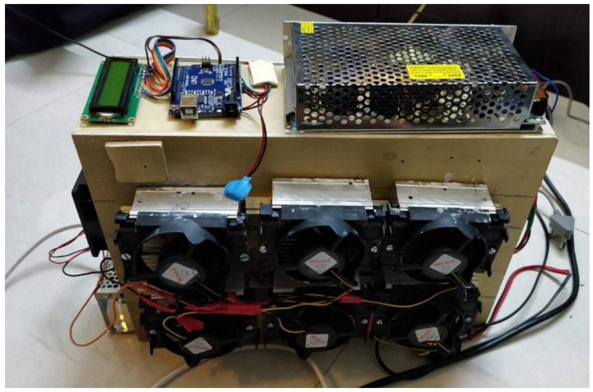
Model No. : TD1225MB

Power Required : DC 24V -0.2A

RPM : 3000-3005 rpm

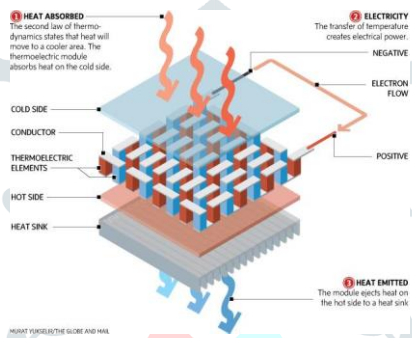
2.2.6 **FINAL MODEL**





III. PELTIER AIR COOLING SYSTEM

A general view of the experimental set-up is as shown. The prototype uses the Peltier effect to lower the temperature of the incoming air. The Peltier plate or Peltier module is a semiconductor plate, when the electric current flows through the module Peltier Effect occurs, due to which one side of the plate becomes extremely cold and the corresponding opposite of the module becomes hot.



PELTIER EFFECT, an effect whereby heat is given out or absorbed when an electric current passes across a junction between two materials.In a circuit consisting of a battery joined by two pieces of copper wire to a length of bismuth wire, a temperature rise occurs at the junction where the current passes from copper to bismuth, and a temperature drop occurs at the junction where the current passes from bismuth to copper.

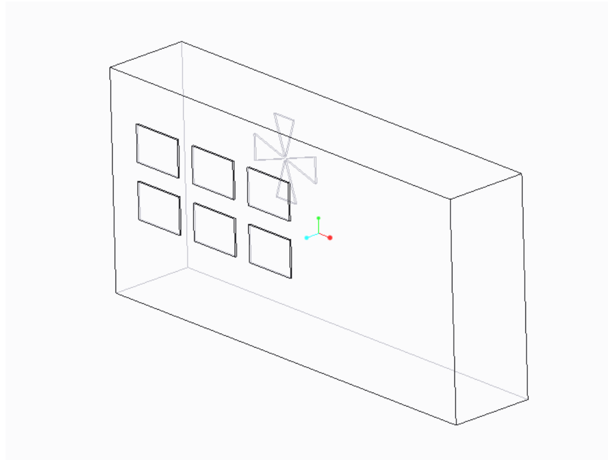
The model uses three pairs of Peltier modules which are placed in parallel fashion on the opposites of the main body, such that each module's cold side is in front of the other module. The cold sides of the modules is attached to copper coils. In the proposed model copper coils are provided which are essentially mounted on a pair of Peltier module. There are two types of coils which are vertical and horizontal in orientation. The coils are designed such that it produces maximum hindrance for the air flow. As the copper coils are in contact of the cold side of the module, eventually their temperature also reduces.

Air fluid flows from the back of the model where the blowers are installed. The blowers pump the environmental air into the body of the model. This air then flows over the copper coils. Since the copper coils are cooled the air also cools down to a considerable temperature.

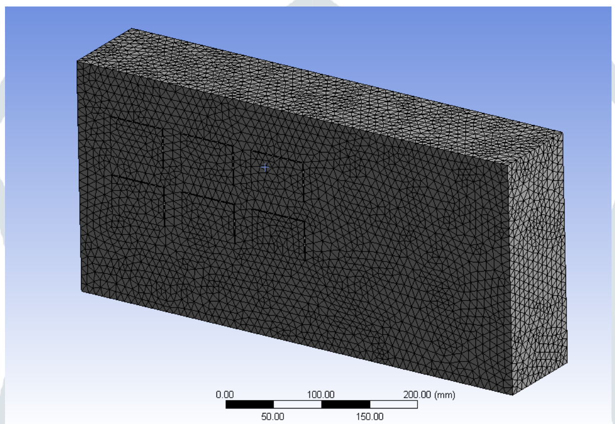
The additional features of the design are that the model is capable of working independently and also as a component. This feature gives the model an advantage so as to be used in large areas as well as small areas. The models works well independently as the working described above, but when catering to large areas many number of these models can be used in series or as well as in parallel so as to cater our needs. Also each and every component of the model can be integrated as per the size required.

IV. ANSYS ANALYSIS

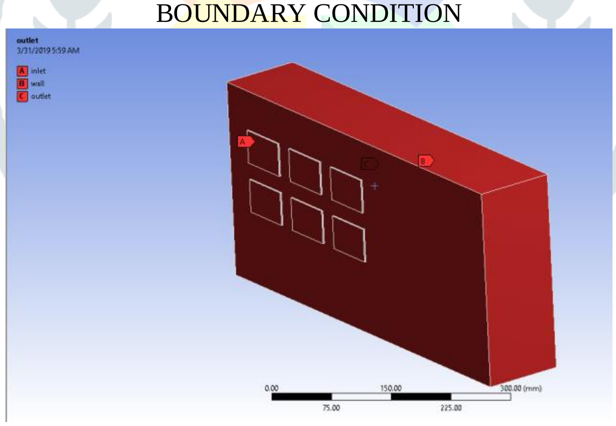
DOMAIN EXTRACTED FROM CAD MODEL FOR CFD ANALYSIS



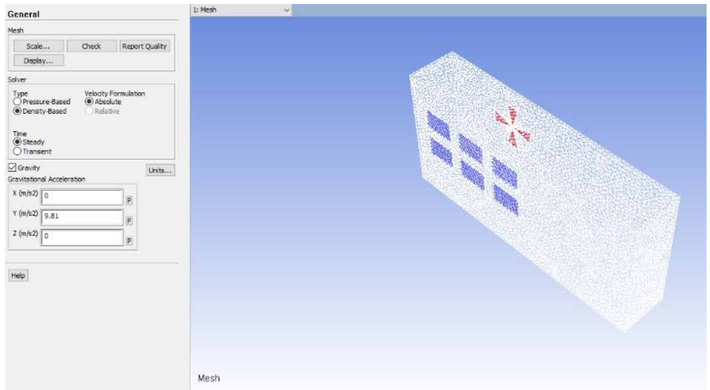
MESHING



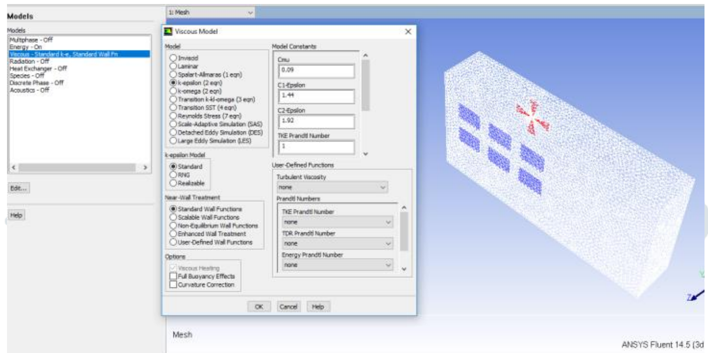
BOUNDARY CONDITION



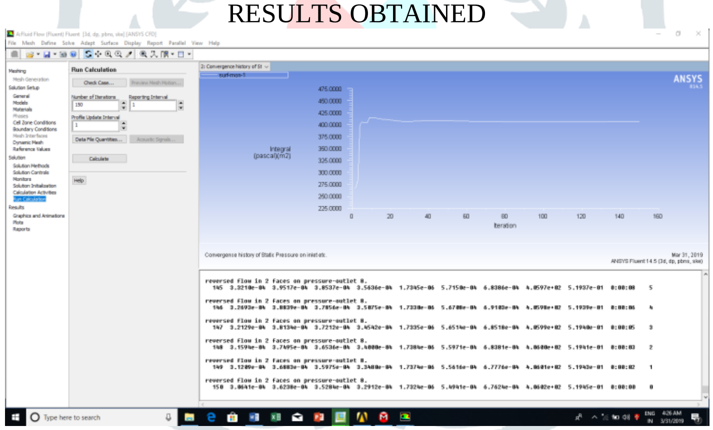
DENSITY BASED SOLVER

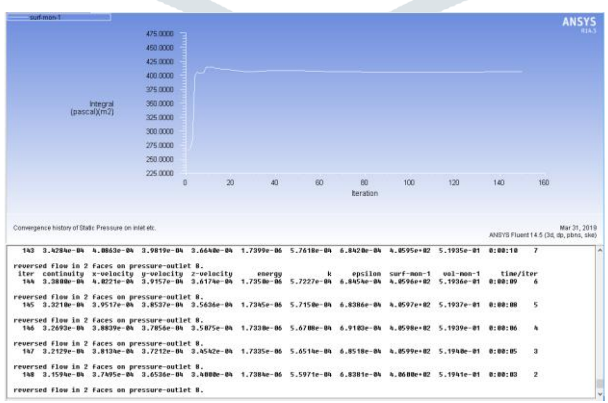


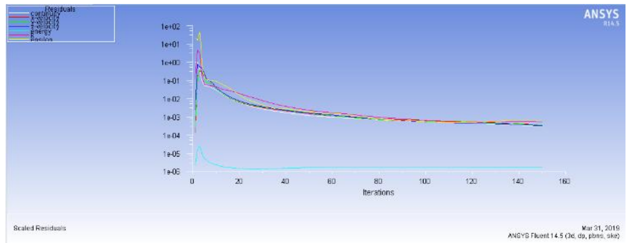
ANALYSIS MODEL

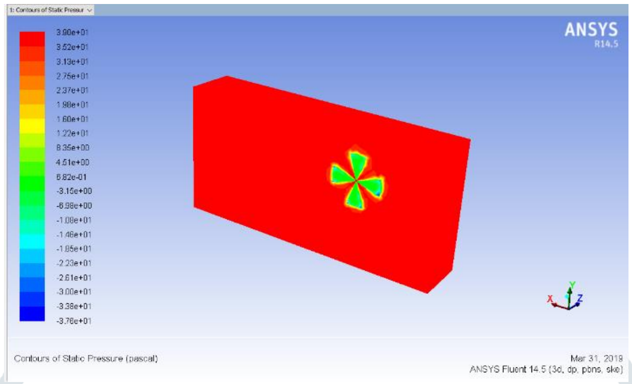


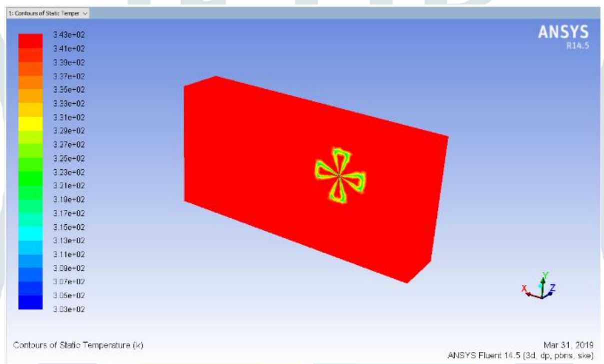
RESULTS OBTAINED

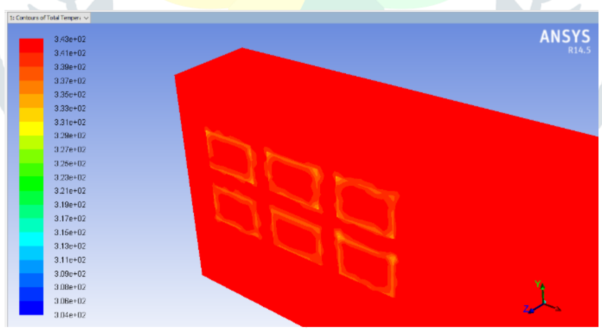


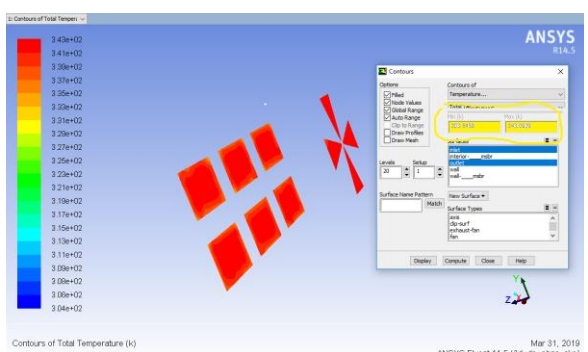


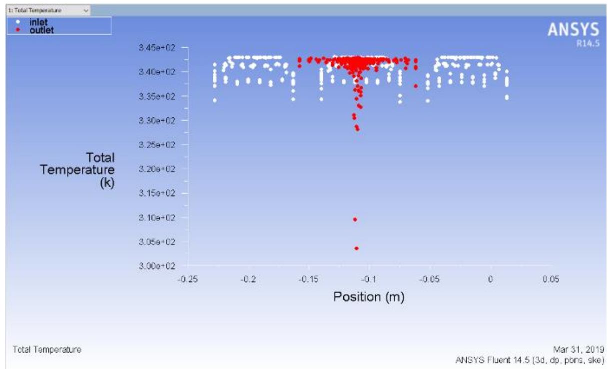

ANSYS
R14.5
Iterations
Scaled Residuals
Mar 31, 2019
ANSYS Fluent 14.5 (3d, dp, pbns, ske)

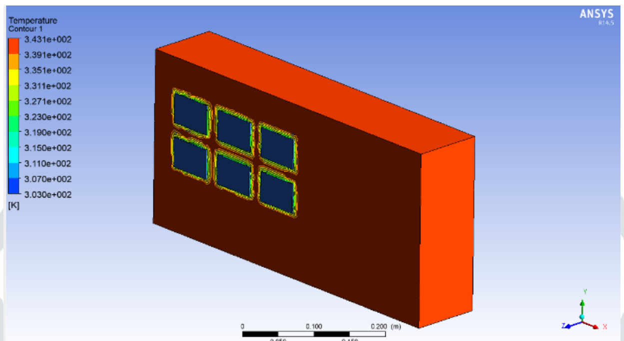

ANSYS
R14.5
Contours of Static Pressure (pascal)
Mar 31, 2019
ANSYS Fluent 14.5 (3d, dp, pbns, ske)

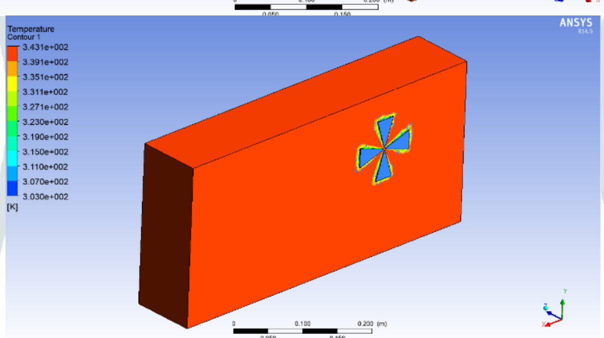

ANSYS
R14.5
Contours of Static Temperature (k)
Mar 31, 2019
ANSYS Fluent 14.5 (3d, dp, pbns, ske)

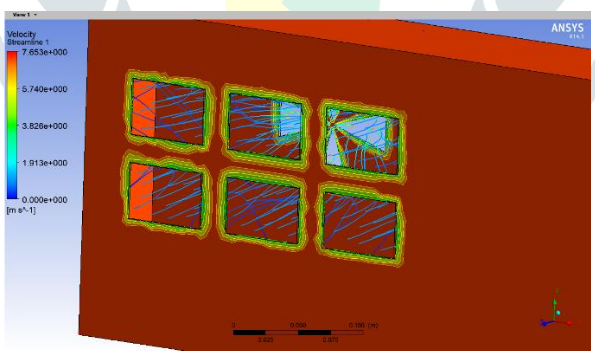

ANSYS
R14.5


ANSYS
R14.5
Contours of Total Temperature (k)
Mar 31, 2019
ANSYS Fluent 14.5 (3d, dp, pbns, ske)









1. File Report

Table 1. File Information for FFF

Case	FFF
File Path	C:\Users\ADMIN\Desktop\CCFD\second_files\dp0\FFF\Fluent\FFF-1-00150.dat.gz
File Date	31 March 2019
File Time	04:42:22 AM
File Type	FLUENT
File Version	14.5.0

2. Mesh Report

Table 2. Mesh Information for FFF

Domain	Nodes	Elements	Tetrahedra	Wedges	Pyramids	Hexahedra	Polyhedra
N____msbr	26170	136163	136163	0	0	0	0

Table 3. Mesh Statistics for FFF

Domain	Minimum Face Angle	Maximum Face Angle	Maximum Edge Length Ratio	Maximum Element Volume Ratio	Connectivity Range	
N____msbr	8.88533 [degree]	126.225 [degree]	6.47428	15.9096	1	38

3. Physics Report

Table 4. Domain Physics for FFF

Domain - N____msbr	
Type	cell

V. TESTING RESULT

Peltier air cooling system has been designed and its fesibility analysis has been done by doing no of iterations, by changing the no. of peltier plates and by amending the materials, desired cooling effect i..e. temperature of air from 35 ^{0}C to 28 ^{0}C to 30 ^{0}C.

VI. CONCLUSION

Peltier modules have great potential for application in domestic appliances in refrigeration and air conditioning. The Peltier Air Cooling System offer an environment friendly and very silent solution over the present conditioning system.

Introduction of Peltier plates in the air cooling system has shown a promising improvement in the performance of such a new device. Even if it could be possible to design a device that operates for both i.e. for cooling as well as heating purpose.

Comparatively it is less efficient than the current air conditioning systems and due to its size, it can't be widely used. But there is a huge scope of research in this field about air cooling system using Peltier plates as they have high potential of heating and cooling. And if done on a large scale using more plates and more investment, the same can be derived to larger and efficient unit.

VII. FUTURE SCOPE

In this peltier air cooling system further improvements are possible as requirement for the more cooling can be achieved within the same cost and less usage of electricity. Looking at the present scenario of increasing pollution this device has a great future scope. In future, there can be some developments in the unit which are listed as follows:

- More cooling can be managed.
- Development of unit according to the space to be conditioned.
- Use of PLC's to automatically sense the temperature and start the blowers.
- Humidifiers and Dehumidifiers can be added suitable to the environment where required.
- If drafted on a larger scale, can be very helpful on the commercial level due its minimum cost of production

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