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DESIGN AND ANALYSIS OF PORTABLE SOLAR THERMO-ELECTRIC AIR CONDITIONER

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Abstract: *Removing heat from a material under carefully monitored circumstances is known as refrigeration. A reversed heat engine or heat pump is used in refrigerators to move heat from a cold body to a hot body. To move heat from a cold body to a hot one, a heat pump needs refrigerant. A variety of methods are employed to accomplish refrigeration, such as the absorption system, the vapour compression system, and the steam jet refrigeration cycle. Solid-state devices known as thermoelectric couplings can either produce electrical power from a temperature gradient (see Beck effect) or transform electrical energy into a temperature gradient (Pelletier effect). The tool suite from C&R Technologies has built-in techniques that allow the thermal designer to simulate thermoelectric coolers or Peltier modules in addition to standard Bismuth Telluride coolers or modules composed of various semiconductor materials. The analysis is done with ANSYS APDL Workbench, and the solar air conditioner module is made with modelling software like CATIA V5. The TEC routine series allows the designer to determine critical size data associated with cooler performance and models single-stage or multi-stage coolers. The process of directly generating power from sunshine is known as solar electricity. The solar or photo-voltaic modules on which it is built are incredibly dependable and don't need fuel or maintenance. When there is no main electricity, solar electric systems work best in areas with lots of sunlight.*

I- INTRODUCTION

"Every new research and invention still aim to be "faster, mightier, and smaller." We focus on the efficiency and compactness of every product in our daily lives. We created the "Solar Air Conditioner," a dependable and affordable device, with this in mind. The mental state that manifests itself in the thermal environment is known as human comfort. We have achieved two competing characteristics in our project: cool air and cold water. Continuous use of this system is possible. A separate air conditioner is not necessary while using our system.

1.1 Description of the Project

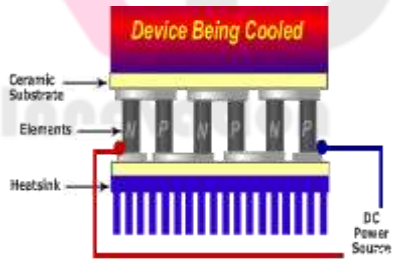

Fig: 1.1: Cooling process by ceramic substance

"CHANGE" serves as the foundational theme word for the mechanical engineering field. People's requirements and the latest developments in technology have prompted us to consider this initiative. Our idea

addresses both human comfort and air temperature regulation, marking our first foray into this area.

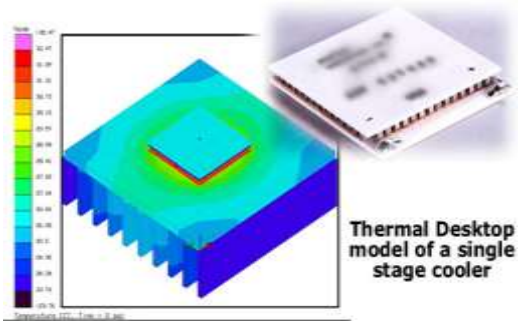

Fig: 1.2: Thermostatic Substance

The Peltier effect, often referred to as thermoelectric couplings, is a solid-state phenomenon that can either generate electrical power from a temperature gradient (the Seebeck effect) or convert electrical energy into a temperature gradient. A basic thermoelectric module consists of two ceramic surfaces that house and electrically separate P-type and N-type (usually Bismuth Telluride) components. At the cold junction, electrons absorb heat by transitioning from a low energy level in the p-type element to a higher energy level in the n-type element. At the hot junction, electrons move from a high-energy element to a low-energy element, releasing energy to a thermal sink. A module consists of several P-N couplings that are electrically coupled in series and thermally coupled in parallel.

1.2 Project Objective

Solar electricity is the direct conversion of sunlight into electrical power. It is powered by photo-voltaic, or solar, modules, which are incredibly dependable and don't need fuel or maintenance. Solar electric systems are ideal for circumstances without main energy and perform best in locations with abundance of sunlight. Our general goal is to construct and assess a "solar air conditioner."

II – REVIEW OF LITERATURE

2.1 Thermal Exchange in Human Body

While other technology can withstand a broad variety of temperatures, the human body can only function at specific temperatures. To keep thermal homeostasis, the human body transfers heat by convection, radiation, and evaporation.

Aspects Influencing Human Comfort

When creating any comfort system, the following factors are essential to take into account: Effectiveness Temperature Air moisture content, air motion, air stratification, human body heat generation and management, and body heat and moisture loss Frostbite, heat exhaustion, heat cramps, heat stroke, hypothermia, and hyperthermia are among the physiological risks connected to heat and acute cold.

The Meteorological Department's Report on Normal Conditions

S. No.	Contents	Hyderabad	Chennai
1.	DBT	34.7°C	36.3°C
2.	WBT	27.5°C	28.5°C
3.	RH	58%	72%
4.	ET	30°C	32°C

2.2 Battery

Batteries are employed in remote systems that are not connected to the grid to store extra solar energy that is transformed into electrical energy. Storage facilities for drinking water or isolated sunny loads, such irrigation pumps, are the only exceptions. In fact, for little gadgets that generate less than one kilowatt. Technically and economically, batteries seem to be the only viable storage option. since the capital costs of the photovoltaic system and batteries are both substantial. Optimizing the system as a whole in terms of available energy and local demand patterns is essential. A battery must have a specific set of characteristics in order to be economically viable for storing solar electricity: (1) Affordable; (2) long-lasting; (3) highly reliable; (4) highly effective overall; (5) low discharge; (6) less maintenance Efficiency in watts and amperes per hour

The following describes the lead acid cells. For street lighting, we store the electrical energy from the solar panel in lead acid batteries.

2.2.1 Lead-Acid Wet Cell

The most popular cell type for situations requiring high load current levels is the lead-acid cell. The electrolyte is a solution of mild sulphuric acid (H_2SO_4). For example, the current flowing to the car's starter when the battery is utilised to start the engine. An average motor draws 200–400 amps. Although the typical output of a single lead-acid cell is 2.1V, they are often used in series, with six cells for a 12-V battery and three for a 6-V battery. Lead acid cells are secondary or store cells that can be recharged.

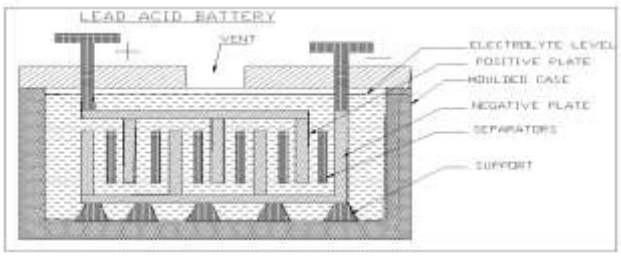

Fig: 2.1: Lead acid battery

Numerous plates that are welded to a connecting strap make up a lead-acid battery's positive

and negative electrodes. The electrolyte, immersed in the plates, is composed of three parts concentrated sulphuric acid and eight parts waters. Each plate functions as a framework or grid and is made of a lead-antimony alloy. This architecture makes it possible to paste the active ingredient, lead oxide, onto the grid. During cell manufacture, the positive and negative electrodes are created by a forming charge. During the forming process, lead peroxide (pbo_2) replaces the active ingredient in the positive plate. Soggy lead (Pb) serves as the negative electrode. Car batteries are typically sent from the manufacturer dry. The battery is charged from the plates once the electrolyte is added during installation. In regular operation, little to no water needs to be added to maintenance-free batteries. With the exception of a pressure vent, some varieties are sealed and do not have a water addition feature. The figure depicts the battery's building components.

- **Chemical Action**

Sulfate and hydrogen ions combine to form sulfuric acid. Lead peroxide from the positive electrode reacts with sulfate ions to generate lead sulphate and with hydrogen ions to form water when the cell discharges. On the negative plate, sulphate is likewise created when lead and sulphate ions are mixed together. As a result, discharge often results in more water and lead sulfate on the plates, diluting the electrolyte. As the discharge proceeds, the sulphate slows down the acid circulation in the active material by filling the grids' pores Lead sulfate is a powder found in the exterior terminals of older batteries. Charging is required when the battery's output is reduced due to both low electrolyte and sulfating on the plate. When charging, the external D.C. source reverses the battery's current. The electrolyte's chemical reactions are inverted because the ions are travelling in the other direction. The lead sulphates on the positive plate now react with the sulphate ions and water to form sulphuric acid and lead peroxide. The addition of sulphuric acid strengthens the electrolyte and reforms the positive plates.

2.4 Condenser

An essential part of the high-pressure side of a refrigeration system is the condenser. Heat extraction from the released refrigerant vapour is the compressor's function. The heat that the evaporator collects is combined with the mechanical energy of the compressor motor to produce the heated vapour refrigerant. Following the transfer of heat from the hot vapour refrigerant to the tube walls, condenser tubes are formed to the condensing or cooling medium.

- **Fin and Tube Condenser**

One type of condenser that uses air to remove heat is the fin and tube. The pipe that the refrigerant passes through is made of copper or steel. Typically, the tube's outside diameter falls between 6 and 18 mm, contingent on the condenser's dimensions. Copper tubes are frequently utilized due to their superior heat transmission capabilities. In order to improve the surface area for heat transfer, the tubes are typically equipped with fins of the plate type. Aluminums is typically used to make the fins due to its low weight. Heat transfer is most effective in condensers with a single row of tubing.

Fig: 2.4: Air Cooling Condenser

This is due to the fact that air's temperature rises as it passes through each tube row. The efficiency of each tube row decreases as the air-vapor refrigerant temperature differential decreases in each row. Nevertheless, single-row condensers were still larger than multi-row ones.

2.5 DC Blower

Within the shell, the impeller, or fan, revolves. The air is forced out of the shell by its design. The blower is made up of two major components. They are fan impeller blades for D.C. motors. The impeller blades and the D.C. motor are directly connected. A water pump is used to circulate the water to the blower. It pushes out the cold air. When the battery is linked to the D.C. motor, it can start up right away.

2.5.1 D.C Motor

The D.C. motor regulates the flow of hot air. Our concept evenly distributes hot air in all directions using a D.C. motor tilting mechanism. The Operational Principle A simple graphic captures the essence of motor motion. The working principle states that a current-carrying conductor is pushed away from a magnetic field by the force created when it is placed in the field.

III – WORKING PRINCIPLE

The lead acid battery is charged using a solar panel. For demonstration purposes, we are utilising a 12-volt, 10-watt panel here. The thermo-electric zip cooler is powered by a battery. The water is first stored inside the zip cooler. The Seebeck effect is the mechanism

that cools this water. We have two choices in our zip cooler.

1. Cold Water
2. Hot Water

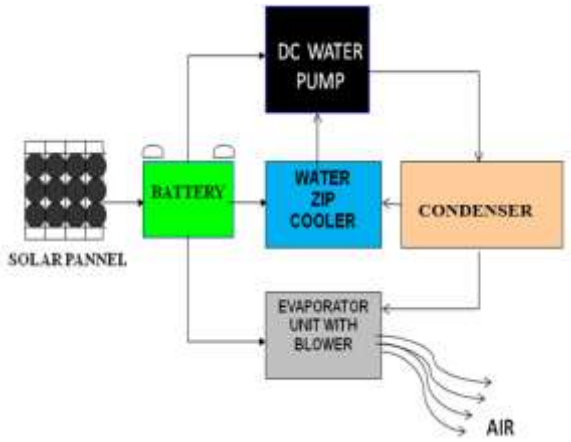

Fig: 3.1: Working principle

To alter the water between those two modes, a single switch is utilised. The evaporator unit receives this water through the D.C. reciprocating water pump. In front of the condenser, a D.C. high-speed blower is installed to force the cooled air out. When two semiconductor materials are electrically linked, free electrons go from the n-type to the p-type through an external electrical conductor (figure). In this instance, when the free electrons enter the holes and become bound electrons, the hole and the free electrons will both be annihilated. Electrons travelling through an external conductor will produce an electric current as long as solar radiation is producing free electrons and holes.

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4.1 Benefits of Solar-Powered Air Conditioners

Simple in terms of construction, analysis, and design when in use, this technology produces no noise. Because of its portability, it may be effortlessly moved to any location. It is battery-operated. Low maintenance costs It uses a solar panel. This project is therefore unconventional. Another usage for solar panels and batteries is as a lighting system.

4.2 The Drawbacks of Solar-Powered Air Conditioners

It doesn't clean the air.

4.3 Uses for Solar-Powered Air Conditioners

Utilisation at Home Application for Office and Bank It is quite beneficial in schools and colleges.

V – DESIGN METHODLOGY OF SOLAR-ELECTRIC AIR CONDITIONER

5.1 Introduction to CATIA

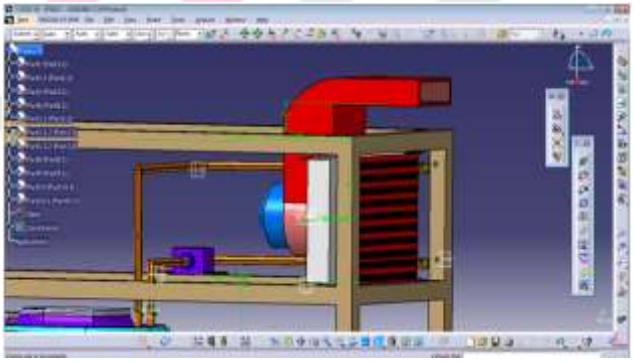
The multi-platform commercial software package known as CATIA (Computer Aided Three-dimensional Interactive Application) for CAD, CAM, and CAE was created by a French firm named Dassault Systems. The foundation of Dassault Systems' product lifecycle management software package, CATIA, is written in the C++ programming language.

Cero Elements/Pro and NX (Unigraphics) are competitors of CATIA in the high-end CAD/CAM/CAE sector. In 1999, Dassault Systems launched CATIA V5, a 3D CAD program. It was a completely new design tool that was a significant departure from CATIA V4. Standard software packages such as SAPR3 products, Microsoft Office, and several graphic programs can be easily integrated with the user interface, which now has an MS Windows layout, depending on the IT environment.

5.4 Modeling of Portable Solar – Electric Air Conditioner in Catia V5

The CATIA V5 program was used to create this air conditioner. Automotive, aerospace, consumer products, heavy engineering, and other industries use this software. For creating intricate 3D models and CATIA Version 5 applications like part and assembly design, this software is incredibly strong.

Below is a reference to the same CATIA V5 R20 3D model and 2D sketch model. Dimensions are obtained from. The 3D model is designed using CATIA V5, and we use the software listed below to conduct tests.



Manipulate: With the use of this command, the component can be turned, rotated, or otherwise manipulated in any direction that is necessary or appropriate constraints can be applied.

Fig: 5.27: Using Manipulate Command

Multi View: This command allows all of the component or model views to be shown on the screen simultaneously and allows editing of them under the workbench.

Fig: 5.28: Using Multi View Command

VI – ANALYSIS OF PORTABLE SOLAR-ELECTRIC AIR CONDITIONER

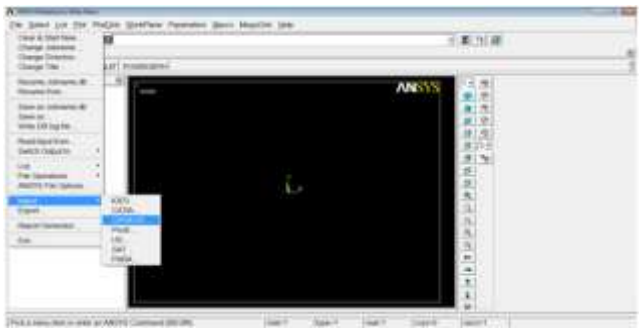
6.1 How to Use ANSYS for FE Analysis

With ANSYS, the blower, pump, pipelines, square frame, condenser, and air outlet are all analysed. Competent assembly is not necessary; instead, the motor and associated gear system must be operated by applying moments at the rotational point along the axis that we must specify. The bottom legs of the machine assembly are the fixing position.

6.2 Preprocessor

The following actions were taken at this stage:
• Use the ANSYS window to import the file. STEP > File Menu > Import Click "OK" to open the dialogue window. Click.

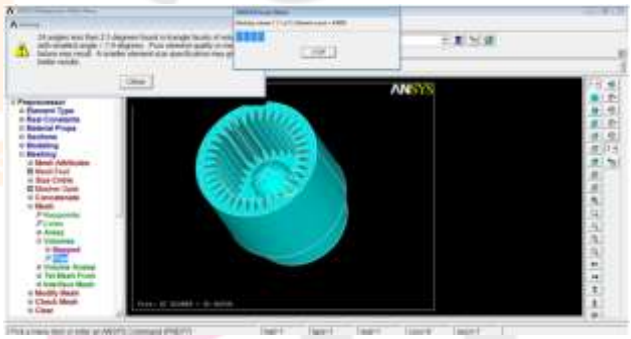
Select the file saved from CATIAV5R20 by selecting "Browse." To import the file, click "OK."

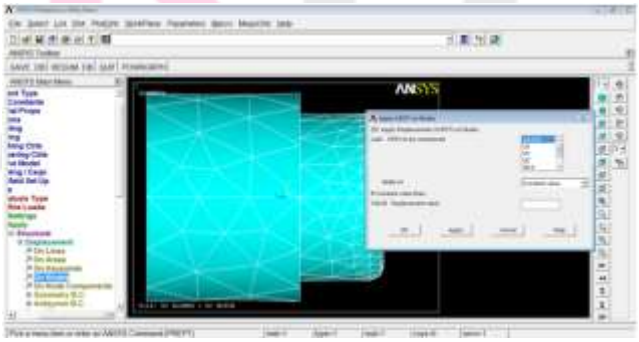


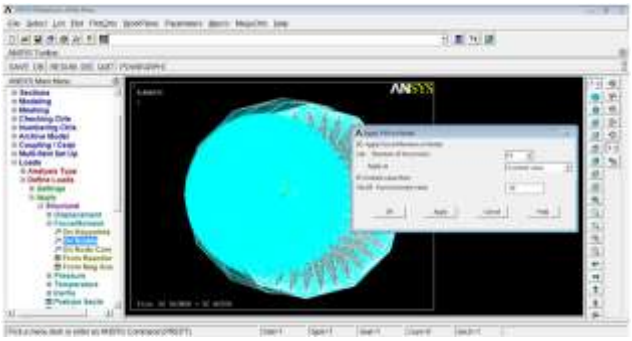
Ansys import panel (Fig. 6.1).

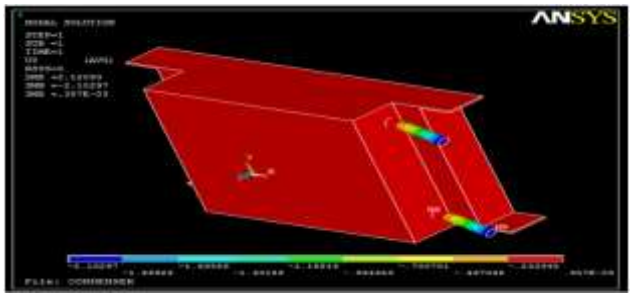
6.3 Analysis Procedure of Portable Solar – Electric Air Conditioner:

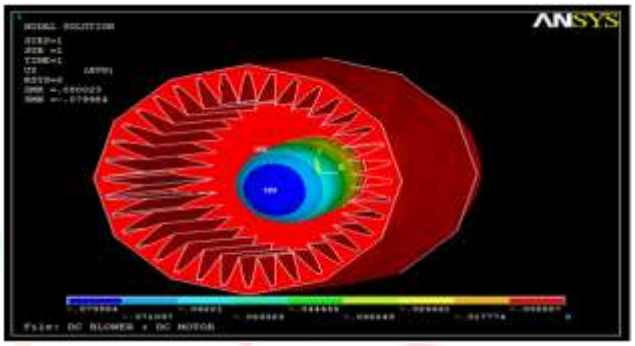
Tetrahedral elements that model irregular meshes (such as those created by various CAD/CAM applications) effectively use their quadratic displacement behavior. There are three degrees of freedom for each of the ten nodes that comprise the element: translations in the nodal x, y, and z directions.

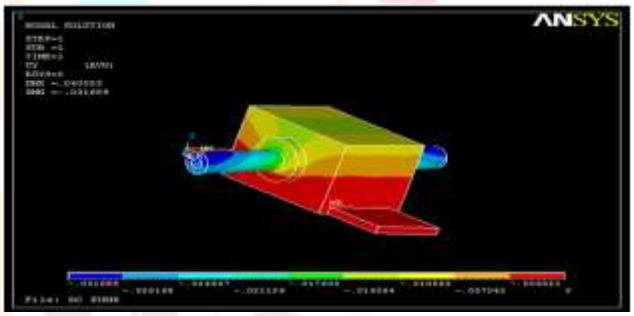


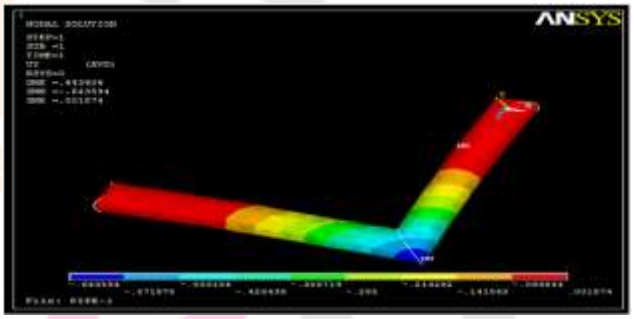


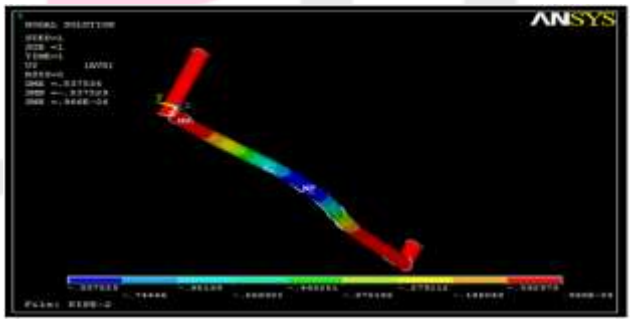








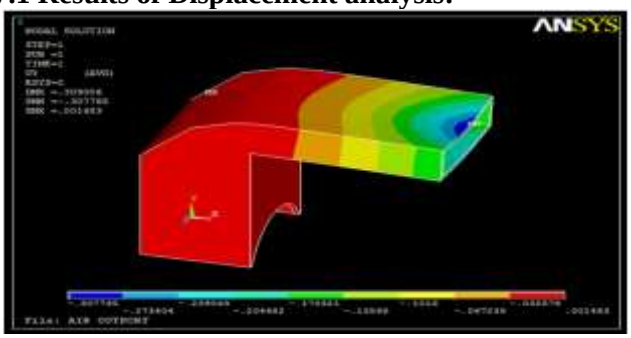


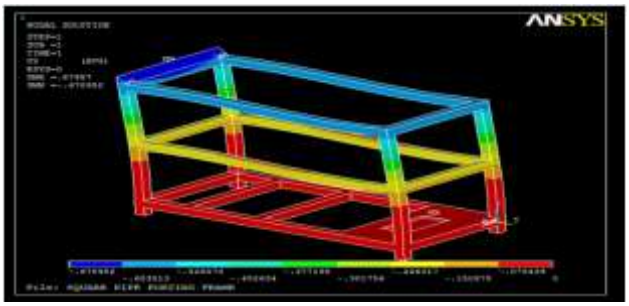


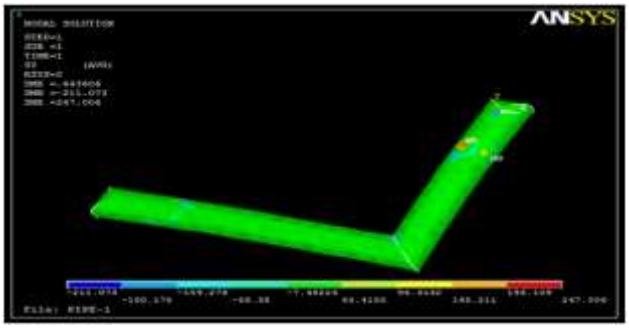
A few components are solved using rotational/force analysis in order to verify the stress and displacements during rotation. After every assembly component has been meshed, an OEM (Original Equipment of Manufacturer) application-based analysis is carried out. We must thus indicate which axis all rotated models are employed along in the analysis software in order to get accurate results that correspond to the original component. To solve some of the components, static analysis is required. The geometry and material properties are listed.

VII – DISCUSSION ON ANALYSYS RESULT

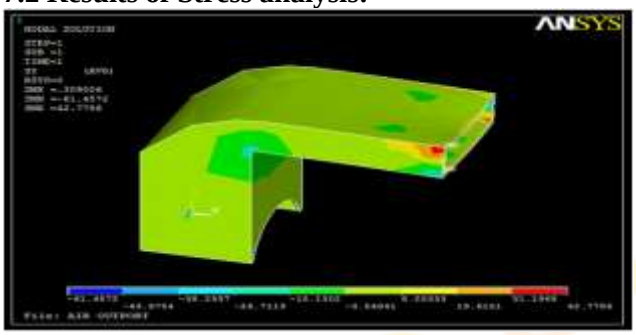
7.1 Results of Displacement analysis:

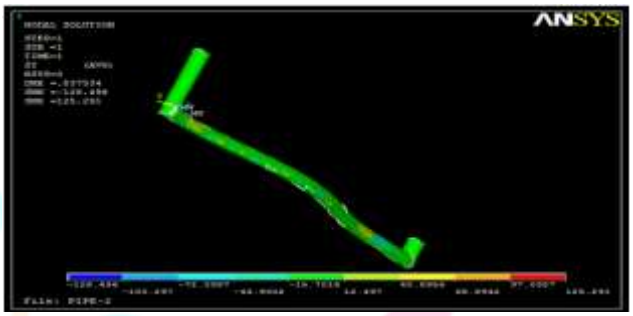


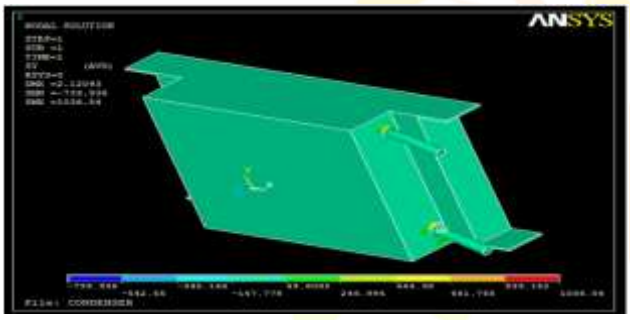


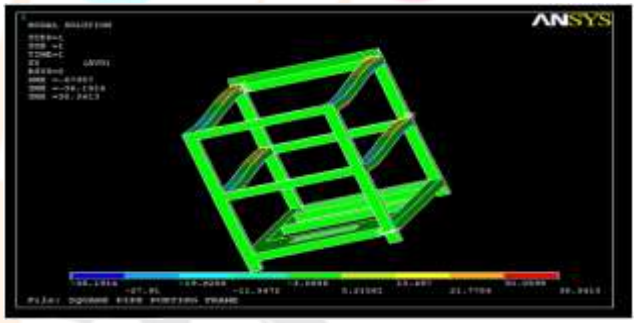


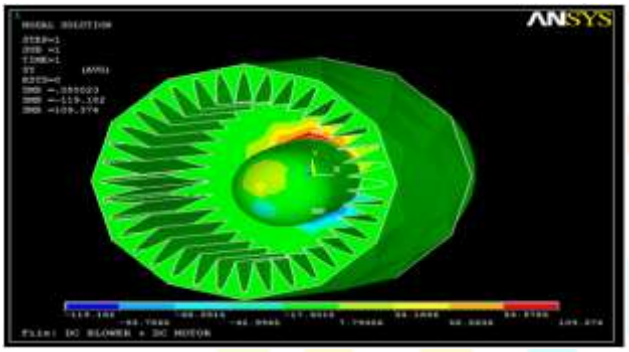
7.2 Results of Stress analysis:



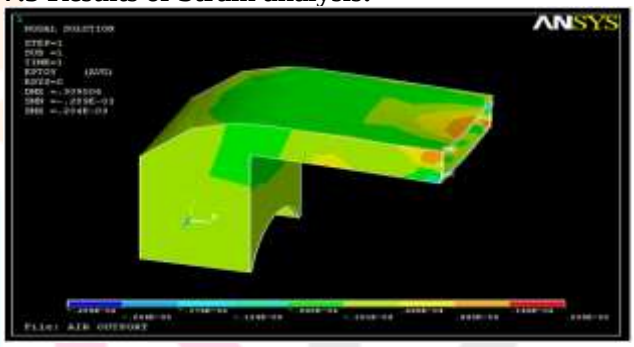


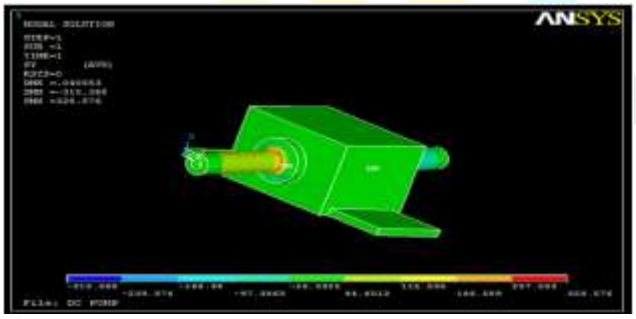


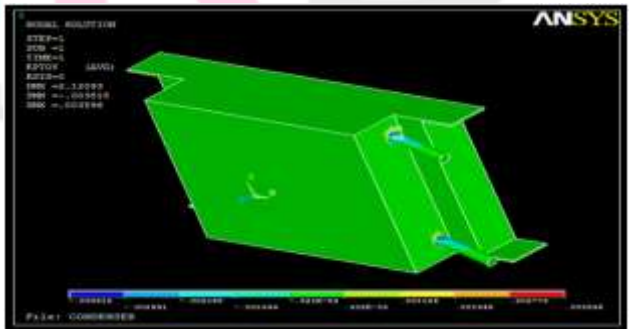


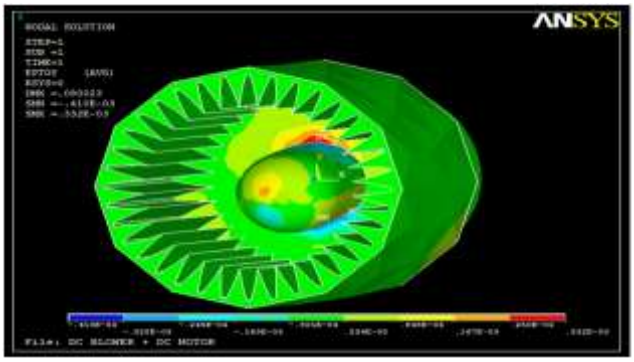


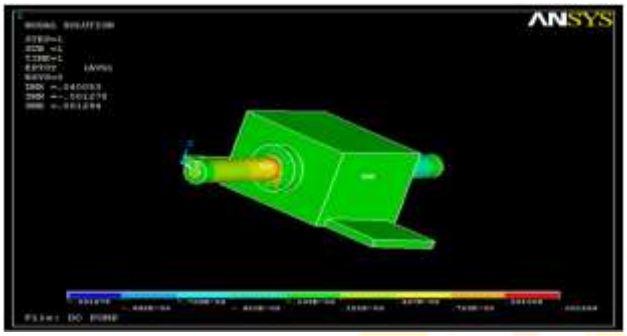
7.3 Results of Strain analysis:

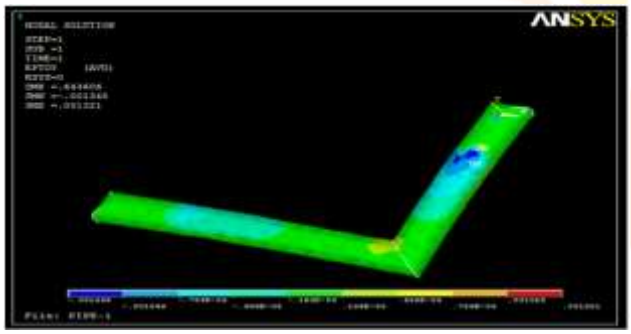


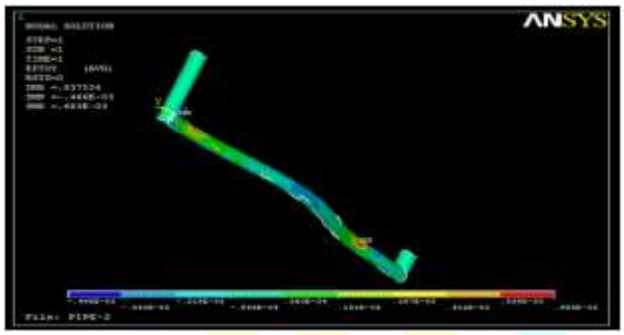


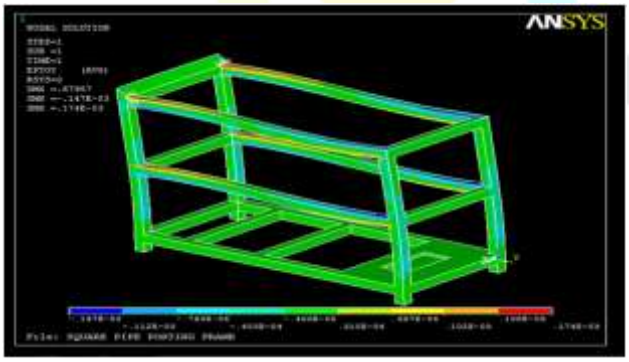












The meshed and Ansys-solved displacement numbers above demonstrate how little displacement there is. This demonstrates to us the obvious slight displacement of every component in the assembly. The stress is at the fixed position (the allowed minimum stress), and its value is 0.679 MPa. Below the yield threshold, the value is exceptionally low in relation to mild steel's yield value. With the use of Ansys software, this method will lessen the impending maximum stress. Consequently, we may say that our design parameters are approximately correct. The outcome was positive. The design assembly of the machine is in perfect condition to help the thermal designer create thermoelectric cooler modules, C&R Technologies' tool suite includes integrated procedures for modeling modules made of different semiconductor materials or standard Bismuth Telluride coolers. In addition to offering important sizing information on cooler performance, the TEC routine series allows the designer to model single-stage or multi-stage coolers. New technological and scientific advancements that benefit humanity are developed daily in the dynamic world of today. The solar air conditioner concept is slightly modified in this work by adding an air cooler. It is possible to use wasted energy to produce even more useful things.

VIII – CONCLUSION

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